

**A PROTEIN BELONGING TO THE TNF SUPERFAMILY INVOLVED IN  
SIGNAL TRANSDUCTION, NUCLEIC ACIDS ENCODING SAME, AND  
METHODS OF USE THEREOF**

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**GOVERNMENT RIGHTS CLAUSE**

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**FIELD OF INVENTION**

The present invention relates to the identification and characterization of a protein belonging to the TNF superfamily which is involved in signal transduction, nucleic acids which encode the protein, and uses for the nucleic acids, the protein, and  
15 products derived therefrom, such as antibodies and pharmaceutical compositions. In particular, the protein of the present invention is involved in the modulation of the survivability of mature dendritic cells of the immune system. As a result, the present invention has numerous uses including, but not limited to, modulating immune response to an antigen, diagnosing immune system related conditions, and treating  
20 immune system related conditions.

**BACKGROUND OF THE INVENTION**

Mature dendritic cells are specialized cells that play a role in immune response. They develop from pluripotent hemopoietic stem cells located in bone marrow, and  
25 function to present antigens on their surface in order to activate T cells and generate an immune response to a particular antigen. Major Histocompatibility Complex (MHC) proteins, such as Class I MHC molecules and Class II MHC molecules, are involved in the presentation of an antigen on the surface of a mature dendritic cell. The activation of T cells involves a costimulatory process. One signal is from the  
30 antigen bound the MHC molecule on the surface of the mature dendritic cell. This complex interacts with the T cell receptor complex on the surface of the T cell. The other signal results from molecules produced by the mature dendritic cell, which bind to receptors on the T cell. The T cell becomes activated upon receiving both signals,

and undergoes an autocrine process wherein it separates from the mature dendritic cell and simultaneously secretes a growth factor like IL-2 along with cell-surface receptors that bind to it. The binding of IL-2 to its receptor stimulates the T cell to proliferate, so long as it has already encountered its specific antigen.

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Once the T cell disengages from the mature dendritic cell, another T cell can bind the MHC - antigen complex on the surface of the mature dendritic cell, and be activated. Hence, the longer an antigen presenting mature dendritic cell can survive, the greater the number of T cells it can activate, and the immune response to the specific antigen will be more efficient. However, pluripotent hematopoietic-stem cells are constantly undergoing differentiation, and new dendritic cells are constantly being produced. In order to maintain and develop the immune system, mature dendritic cells ultimately undergo apoptosis, wherein its nucleus shrinks and condenses, and the cell shrivels and dies. Newly produced mature dendritic cells are constantly replacing these dead and dying mature dendritic cells.

Members of the tumor necrosis factor (TNF) cytokine family can regulate apoptosis in addition to an array of other biological effects, such as cell proliferation, and differentiation. The TNF cytokine family currently includes TNF, LT- $\alpha$ , LT- $\beta$ , FasL, CD40L, CD30L, CD27L, 4-1BBL, OX40L (1) and TRAIL/APO-2L (2, 3) which exhibit the highest homology between their C-terminal, receptor binding domains. The family members are type II membrane proteins that act in an autocrine, paracrine or endocrine manner either as integral membrane proteins or as proteolytically processed soluble effectors. Despite the functional redundancy of this family, specificity may be accomplished by coordinating the spatial and temporal expression of TNF-related ligands and their receptors, and by restricting the expression of signal transduction molecules to specific cell types. TNF receptors interact with a family of molecules called TRAFs (TNF receptor associated proteins) that act as adaptors for the downstream signaling events. Hence, binding of a TNF cytokine to its cognate receptor, which is interacting with TRAF, leads to the activation of several signal transduction pathways, including the activation of the cascade of caspase/ICE-like

proteases, which are responsible for apoptosis. Also activated is the nuclear factor- $\kappa$ B (NF- $\kappa$ B) family of transcription factors, which inhibit apoptosis, and mitogen activated protein kinases including the c-Jun N-terminal protein kinases (JNK) and the extracellularly-regulated kinases (ERK).

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Moreover, the TNF receptor family can also regulate apoptosis by modulating the expression of the proto-oncogene *bcl-2* to produce Bcl-2 and Bcl-2 related proteins. Bcl-2 can suppress apoptosis in the cell by altering transmembrane conductance in mitochondria and preventing the activation of the caspase/ICE- like proteases.

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As explained above, the longer an antigen presenting mature dendritic cell can survive, the greater the number of T cells it can activate, and the immune response to the specific antigen will be more efficient. Accordingly, there is a need to be able to increase the active life of antigen presenting mature dendritic cells, and to inhibit

15 apoptosis in such cells.

There is a further need to exploit the increased survivability of antigen presenting dendritic cells to modulate the immune response to an antigen. For example, such increased survivability can be used to diagnose and treat immune system related

20 conditions.

Such increases in mature dendritic cell survivability can also be used to modulate T cell activation in a subject, and thereby modulate the immune response to an antigen.

25 The citation of any reference herein should not be construed as an admission of such reference as prior art.

### SUMMARY OF THE INVENTION

30 The present invention relates to a novel TNF family member membrane bound protein designated TNF-Related Activation Induced Cytokine, hereinafter referred to as

“TRANCE.” TRANCE is selectively expressed on T cells, and its receptor, hereinafter referred to as “TRANCE-R”, has been detected on the surface of mature dendritic cells located in lymphoid tissues, such as the lymph node and thymus. It has been determined that the interaction of TRANCE with TRANCE-R on the surface of a mature dendritic cell results in the upregulation of the expression by the cell of the Bcl-x<sub>L</sub> protein. This protein, related to Bcl-2, suppresses apoptosis in the cell by altering transmembrane conductance in mitochondria and preventing the activation of the caspase/ICE- like proteases. Hence, the exposure of an a mature dendritic cell to TRANCE will increase its life span.

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Thus, in a first embodiment, the present invention relates to an isolated nucleic acid molecule comprising the DNA sequence set forth in Figure 1 (SEQ ID NO:1), or degenerate variants thereof, which correspond to the human TRANCE gene. Moreover, this embodiment extends to an isolated nucleic acid molecule hybridizable to the isolated nucleic acid molecule of Figure 1 (SEQ ID NO:1), or degenerate variants thereof, under standard hybridization conditions. Yet further, the invention includes isolated nucleic acid molecules that encode polypeptides having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), which is the amino acid sequence of human TRANCE, as well as conserved variants thereof.

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In another embodiment, the present invention relates to an isolated nucleic acid molecule comprising the DNA sequence set forth in Figure 3 (SEQ ID NO: 3), degenerate variants thereof, which correspond to the murine TRANCE gene.

Furthermore, this embodiment also includes an isolated nucleic acid molecule hybridizable to the nucleic acid molecule of Figure 3 (SEQ ID NO:3), or degenerate variants thereof, under standard hybridization conditions. Likewise included are nucleic acids molecules that encode the murine TRANCE protein, having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4), as well as conserved variants thereof.

30

Naturally, the present invention extends to the amino acid sequences of human and



murine TRANCE, conserved variants thereof, and fragments of human and murine TRANCE, and conserved variants thereof, wherein the human TRANCE corresponds to the amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), and the murine TRANCE corresponds to the amino acid sequence as set forth in Figure 4 (SEQ ID NO:4).

Also included in the present invention are detectably labeled nucleic acids hybridizable to an isolated nucleic acid having a DNA sequence as set forth in Figure 1 (SEQ ID NO:1), Figure 3 (SEQ ID NO:3), degenerate variants thereof or fragments thereof.

In addition, the present invention also includes antibodies wherein TRANCE, conserved variants thereof, or a fragment thereof, is the immunogen used in production of the antibodies. These antibodies can be monoclonal or polyclonal. Moreover, the antibodies can be "chimeric" as, for example, they may comprise protein domains from anti-TRANCE antibodies raised against TRANCE in different species.

Moreover, the present invention includes an antibody of TRANCE detectably labeled so that its bonding to TRANCE can be detected. Such detectable labels include enzymes conjugated to the antibody, such as alkaline phosphatase or peroxidase, or radioactive isotopes incorporated into the structure of the antibody.

A further embodiment of the present invention extends to an expression vector containing a nucleic acid molecule which encodes TRANCE, degenerate variants thereof, or an isolated nucleic acid hybridizable to the nucleic acid molecule which encodes TRANCE or degenerate variants thereof, under standard hybridization conditions, operatively associated with a promoter. With this expression vector, one may transfect or transform a unicellular host which can then produce TRANCE. The method for expressing TRANCE comprises introducing an expression vector of the present invention into a host cell in a culture to cause a unicellular host into which the

vector is introduced, to express and thereby cell produce TRANCE, and then recovering the TRANCE from the unicellular host, the culture, or both. In one embodiment, an expression vector may comprise the isolated nucleic acid molecule comprising the DNA sequence set forth in Figure 1 (SEQ ID NO:1), operatively associated with a promoter. In another embodiment, the expression vector contains the nucleic acid molecule comprising the DNA sequence of Figure 3 (SEQ ID NO:3) operatively associated with a promoter. An expression vector can be introduced into numerous types of unicellular hosts in order to produce TRANCE, including, but not limited to mammalian cells, insect cells, and bacterial cells.

An expression vector of the present invention can employ numerous promoters to express TRANCE. The promoters applicable to the present invention, include, but are not limited to early promoters of hCMV, early promoters of SV40, early promoters of adenovirus, early promoters of vaccinia, early promoters of polyoma, late promoters of SV40, late promoters of adenovirus, late promoters of vaccinia, late promoters of polyoma, the *lac* the *trp* system, the *TAC* system, the *TRC* system, the major operator and promoter regions of phage lambda, control regions of fd coat protein, 3-phosphoglycerate kinase promoter, acid phosphatase promoter, or promoters of yeast  $\alpha$  mating factor.

As explained above, unicellular hosts can be transformed with an expression of the present invention. Such unicellular hosts include, but are not limited to, *E. coli*, *Pseudomonas*, *Bacillus*, *Streptomyces*, yeast, CHO, R1.1, B-W, L-M, COS1, COS7, BSC1, BSC40, BMT10 and Sf9 cells. Moreover, mammalian cells can be used as a unicellular host.

The present invention also includes a mammalian cell containing an isolated nucleic acid encoding TRANCE, examples of which are described herein, wherein the isolated nucleic acid sequence is modified *in vitro* to permit higher expression of a TRANCE polypeptide in the cell by means of a homologous recombinational event, consisting of inserting an expression regulatory sequence, such as a promoter, in

functional proximity to the TRANCE polypeptide encoding sequence. In such a cell, the expression regulatory sequence can be a TRANCE promoter and the homologous recombinational event replaces a mutant TRANCE promoter. However, numerous promoters described herein can also be inserted in such a cell and result in higher  
5 expression of TRANCE.

Also included in the present invention are nucleic acid fragments of the isolated nucleic acid molecule of the present invention, degenerate variants thereof, and isolated nucleic acid molecules which hybridize to such fragments or degenerate  
10 variants thereof, under standard hybridization conditions. Such fragments may also be inserted into expression vectors and operatively associated with a promoter, which in turn, can be used to cause a host cell in which the vector is introduced to express and thereby produce such fragments of TRANCE.

15 Accordingly, a method for producing TRANCE fragments is included in the present invention, wherein this method comprises the steps of introducing an expression vector of the present invention containing a fragment of TRANCE operatively associated with a promoter into a unicellular host in a culture to cause the host cell into which the expression vector is introduced to express and thereby produce a  
20 TRANCE fragment, and then recovering the produced fragment from the unicellular host, its culture, or both. Examples of unicellular host cells which can be used in this embodiment of the present invention are described above. In one embodiment, the nucleic acid fragment is from the isolated nucleic acid molecule comprising a DNA sequence as set forth in Figure 1 (SEQ ID NO:1), and the nucleic acid fragment  
25 encodes an active peptide fragment of TRANCE. In another embodiment, the nucleic acid fragment is from the isolated nucleic acid molecule comprising a DNA sequence as forth in Figure 3 (SEQ ID NO:3), and the nucleic acid fragment encodes an active peptide fragment of TRANCE. The expression vectors of the present invention can be successfully introduced into numerous types of host cells in order to produce  
30 TRANCE fragments, including, but not limited to, mammalian cells, insect cells, and bacterial cells.

The present invention further comprises a modulator of immune response in a mammal. The modulator can be a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof or a fragment thereof, or a polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof. The modulator can also be an analog or derivative of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof or a fragment thereof, or an analog or derivative of a polypeptide having an amino acid residue sequence as set forth in Figure 4 (SEQ ID NO:4), or conserved variants thereof, or a fragment thereof.

Moreover, the modulator can be a fusion protein comprising an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof or a fragment thereof, or an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof. Other forms of the modulator include an anti-sense TRANCE nucleic acid comprising at least one phosphodiester analog bond, and an antibody, wherein its immunogen is selected from the group consisting of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof, or a fragment thereof, a polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, a fusion protein wherein its amino acid sequence comprises an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof, or a fragment thereof, and a fusion protein wherein its amino acid sequence comprises the amino acid sequence set forth in Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof.

Moreover, also included in the present invention are analogs or derivatives of TRANCE, wherein a water soluble polymer is conjugated to a TRANCE protein. An example of such a polymer is polyethylene glycol. Moreover, an analog or derivative

of a TRANCE protein can be mono-, di-, tri- or tetrapegylated. Moreover, pegylation of TRANCE to form a TRANCE analog or derivative can occur at the N terminus, such that TRANCE is N-terminal monopegylated.

- 5 The function of the modulators is to modulate the life span of mature dendritic cells, and hence modulate immune response in the mammal. In particular, exposure of mature dendritic cells to a modulator which is an agonist of TRANCE, such as a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, an analog
- 10 or derivative of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, a fusion protein wherein its amino acid sequence comprises the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), or conserved variants thereof or a fragment thereof, causes the upregulation of expression of Bcl-x<sub>L</sub>, which
- 15 inhibits apoptosis. As a result, mature dendritic cells have a greater active life span than mature dendritic cells not exposed to TRANCE or an agonist modulator thereof, and hence can activate a greater number of T cells than are activated by mature dendritic cells not exposed to a TRANCE agonist modulator.
- 20 Also disclosed are TRANCE antagonist modulators which function to decrease the active life span of mature dendritic cells. In particular, these modulators can form a complex with TRANCE on the surface of T cells and prohibit it from interacting with TRANCE-R. TRANCE antagonist modulators can also form a complex with TRANCE mRNA, and prevent its translation. As a result, the signal transduction of
- 25 TRANCE is blocked, the upregulation of the expression of Bcl-x<sub>L</sub> in mature dendritic cells does not occur, and apoptosis of the cell is not inhibited. Hence, these mature dendritic cells activate less T cells than are activated by mature dendritic cells exposed to TRANCE, and the immune response in the mammal is decreased. The TRANCE antagonist modulators comprise an anti-sense TRANCE nucleic acid
- 30 comprising at least one phosphodiester analog bond, and an antibody, wherein its immunogen is selected from the group consisting of a polypeptide having an amino

acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof, or fragment thereof, a polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, an analog or derivative of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof or a fragment thereof, an analog or derivative of a polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, a fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), conserved variants thereof or a fragment thereof, and a fusion protein containing the amino acid sequence of Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof.

The present invention also comprises a TRANCE agonist pharmaceutical composition comprising a modulator which is an agonist of TRANCE, and a pharmaceutically acceptable carrier thereof. The TRANCE agonist modulator is selected from a group of modulators of the present invention consisting of an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, an analog or derivative of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, a fusion protein wherein its amino acid sequence comprises the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), or conserved variants thereof or a fragment thereof.

As explained above, it has been determined that exposure of an antigen presenting mature dendritic cell to TRANCE causes upregulation of the expression of Bcl-x<sub>L</sub>, and inhibits apoptosis in a mature dendritic cell. Hence, a TRANCE agonist pharmaceutical composition can be used in a method for treating an immune system related condition in a mammal, wherein the method for treating an immune system related condition comprises the steps of exposing at least one mature dendritic cell of the mammal to an antigen so that the at least one mature dendritic cell can present the antigen on its surface, and administering to the mammal a therapeutically effective

amount of the TRANCE agonist pharmaceutical composition. The exposure of the at least one mature dendritic cell to the antigen can occur *in vivo*, wherein the antigen is administered to a subject, or *ex vivo*, wherein the at least one mature dendritic cell is removed from the mammal and exposed to an antigen in a medium which permits the presentation of the antigen on the surface of the at least one mature dendritic cell. The at least one mature dendritic cell presenting the antigen on its surface is then reintroduced into the mammal prior to the administration of a TRANCE agonist pharmaceutical composition. This method increases the active life of a mature dendritic cell presenting an the antigen on its surface. As a result, the number of T cells activated against the antigen presented on the surface of the mature dendritic cell is increased, which results in an increase in a mammal's immune response to the antigen.

The antigen used in this method can be selected from the group consisting of a pathogen or a fragment thereof, a virus or a fragment thereof, and a tumor, or a fragment thereof. The immune system related conditions treated with this method include, but are not limited to viruses which include, but are not limited to adenoviruses, and viruses related to cancer such as HIV, Papillomavirus, Hepatitis-B, Epstein-Barr virus, and cancer itself.

Moreover, the present invention also includes a TRANCE antagonist pharmaceutical composition, which comprises the modulator which is an antagonist of TRANCE and a pharmaceutically acceptable carrier thereof. The modulator which is an antagonist of TRANCE is selected from the group consisting the anti-sense TRANCE nucleic acid comprising at least one phosphodiester analog bond, and the antibody having an immunogen selected from the group consisting of the polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or a fragment thereof, the polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4) or a fragment thereof, the analog or derivative of the polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or a fragment thereof, the analog or derivative of the polypeptide having an amino acid sequence as set forth in Figure 4

(SEQ ID NO:4) or a fragment thereof, the fusion protein containing the amino acid sequence of Figure 2 (SEQ ID NO:2), or a fragment thereof; and the fusion protein containing the amino acid sequence of Figure 4 (SEQ ID NO:4), or a fragment thereof.

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Yet further provided in the present invention is a TRANCE antagonist pharmaceutical composition which modulates immune response in a mammal by preventing the upregulation of the expression of Bcl-x<sub>L</sub> so that apoptosis is not inhibited in mature dendritic cells. As a result, the life span of mature dendritic cells of a mammal whose  
 10 immune system is exposed to a TRANCE antagonist pharmaceutical composition is decreased relative to the life span of mature dendritic cells in a mammal whose immune system is not exposed to a TRANCE antagonist pharmaceutical composition. The TRANCE antagonist pharmaceutical composition comprises a modulator which is an antagonist of TRANCE, and is selected from the group consisting of an anti-  
 15 sense TRANCE nucleic acid comprising at least one phosphodiester analog bond, and an antibody, wherein the immunogen of the antibody is selected from the group consisting of the polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or a fragment thereof, the polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4) or a fragment thereof, the analog or  
 20 derivative of the polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or a fragment thereof, the analog or derivative of the polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4) or a fragment thereof, the fusion protein containing the amino acid sequence of Figure 2 (SEQ ID NO:2), or a fragment thereof, and the fusion protein containing the amino acid  
 25 sequence of Figure 4 (SEQ ID NO:4), or active fragment thereof, and a pharmaceutically acceptable carrier thereof.

Moreover, disclosed herein is a method for treating an immune system related condition in a mammal with the TRANCE antagonist pharmaceutical composition,  
 30 wherein the method comprises administering to the mammal a therapeutically effective amount of the TRANCE antagonist pharmaceutical composition. As a



result, the signal transduction of TRANCE from the surface of a T cell is blocked, such that TRANCE can not interact with TRANCE-R. the upregulation of expression of Bcl-x<sub>L</sub> in mature dendritic cells does not occur, and apoptosis is not inhibited. An immune system related condition treated with this method involves overexpression of TRANCE on the surface of T cells, and the life span of mature dendritic cells is of such a length as to be detrimental to the mammal. One example of such a condition is an autoimmune disease, such as rheumatoid arthritis. Another example involves hypersensitivity to an allergen so that the mammal's immune response towards an allergen is less severe. As a result, this method of the present invention can be used in induce anergy in the mammal towards the allergen.

In yet another embodiment, the present invention can be used to diagnose an immune system related condition in a mammal, such as a human. As disclosed herein, TRANCE is a member of the TNF super family of proteins. and the exposure of mature dendritic cells to TRANCE ultimately increases the life span of such cells. Hence, just as in the case of other TNF receptor family proteins such as CD40, wherein its under expression results in an immune system related condition called Hyper IGM syndrome, the under expression of TRANCE can also result in an immune system related condition. Moreover, Autoimmune Human Lymphoproliferative Syndrome (ALPS) is a condition caused by a mutation in the TNF receptor family protein Fas, such that the protein is not expressed, or is expressed in a mutated form with either no activity or decreased activity relative to the wildtype Fas protein. Consequently, the under expression or lack of expression of TRANCE in a mammal results in an immune system related condition. Hence, the present invention provides a method for diagnosing such an immune system related condition in a mammal such as a human, wherein the method comprises the steps of removing a bodily sample from the mammal, assaying the bodily sample to determine whether TRANCE is expressed in the sample. The bodily sample can be blood or lymphoid tissue such as lymph node tissue, spleen tissue or thymus tissue.

Such a lack of expression, or under expression, can result from a nonsense mutation in

the gene or cDNA encoding TRANCE whereby TRANCE mRNA is not translated, or it is mutated, and the protein product produced from its translation is nonfunctional, or has decreased function. Hence, the isolated nucleic acids of the present invention which encode TRANCE, and the amino acid sequences of TRANCE disclosed in the  
5 present invention, can be used for diagnosing an immune system related condition in the mammal, such as autoimmune disease.

Antibodies to the modulators are also encompassed within the scope of the present invention. In particular, these antibodies can be monoclonal or polyclonal. Moreover,  
10 chimeric antibodies made against the modulator from at least two species are included in the present invention.

Yet still another embodiment of the present invention is a method of gene therapy for modulating levels of expression of a TRANCE protein in a mammal. Since T cells,  
15 like mature dendritic cells, originate from pluripotent hematopoietic stem cells, and are constantly being produced to replace cells which die from apoptosis, an alteration of the TRANCE gene in a pluripotent stem cell, or the addition of copies of the TRANCE gene operatively associated with a promoter to the genome of the stem cell will modulate the level of expression of TRANCE on the surface of T cells. The  
20 method for accomplishing such modulation comprises the steps of removing at least one hematopoietic stem cell from the mammal, destroying remaining hematopoietic stem cells in the mammal, transfecting the at least one hematopoietic stem cell with a vector containing a nucleic acid molecule which encodes a TRANCE protein such that the nucleic acid molecule becomes incorporated into the genome of the hematopoietic  
25 stem cell forming a transfected hematopoietic stem cell, and introducing the transfected hematopoietic stem into the mammal so that the transfected hematopoietic stem cell can self replicate and differentiate within the mammal. In one embodiment, the nucleic acid which encodes TRANCE has a nucleotide sequence as set forth in Figure 1 (SEQ ID NO:1).

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Accordingly, it is an object of the present invention to provide an isolated nucleic

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acid sequence which encodes a TRANCE protein or a fragment thereof, and degenerate variants of such isolated nucleic acids. Disclosed herein are isolated nucleic acid sequences which encode murine TRANCE and human TRANCE.

- 5 It is a further object of the present invention to provide an amino acid sequence for TRANCE or a fragment thereof, having utility in a pharmaceutical composition which can modulate immune response in a mammal, or procedure intended to diagnose an immune system related condition in a mammal.
- 10 It is a further object of the present invention is to provide an expression vector which can be used to produce TRANCE in a cell, wherein the expression vector comprises the isolated nucleic acid sequence of the present invention which encodes TRANCE, operatively associated with a promoter. A cell transfected with this vector can be made to produce TRANCE, or a fragment thereof, which have  
15 applications as described above.

Yet another object of the present invention is to provide a fusion protein containing a fragment of TRANCE linked to a different protein, or a fragment of a different protein.

- 20 It is a further object of the present invention to provide antibodies to the TRANCE and its subunits, and methods for their preparation, including recombinant means. Such antibodies include polyclonal, monoclonal and chimeric antibodies.
- 25 Yet still another object of the present invention is to provide a modulator of immune response in mammal, wherein this modulator regulates the life span of mature dendritic cells, and hence T cell activation. In particular, one object is to provide a TRANCE agonist modulator can bind to TRANCE-R on the surface of a mature dendritic cells and signal the cell, resulting in an upregulation of expression of Bcl-  
30  $x_L$  in the cell. This protein inhibits apoptosis and hence prolongs the life span of the mature dendritic cells of the mammal. As a result, the number of T cells activated

by a mature dendritic cell exposed to the TRANCE agonist modulator is greater than the number of T cells activated by a mature dendritic cell not exposed to the TRANCE agonist modulator. Hence, immune response is increased.

- 5 Yet another object of the present invention is to provide a TRANCE antagonist modulator which can either bind to TRANCE on the surface of a T cell and prevent its binding to TRANCE-R on a mature dendritic cell, or binds to TRANCE mRNA, preventing its function. The antagonist TRANCE modulator can be an antibody having an TRANCE or a fragment thereof as an immunogen. Moreover, an analog  
10 or derivative of TRANCE, and a TRANCE fusion protein can also serve as an immunogen. The antibody of the present invention which is a TRANCE antagonist modulator can be a polyclonal, monoclonal or chimeric antibody, the production of which are all disclosed in the present invention. The TRANCE antagonist modulator can also be an anti-sense nucleic acid molecule having at least  
15 phosphodiester analog bond which is complement to TRANCE mRNA such that the anti-sense molecule of the present invention can bind to TRANCE mRNA and prevent its function.

- It is a still further object of the present invention to provide pharmaceutical  
20 compositions for use in therapeutic methods which wherein the pharmaceutical compositions comprise, or are derived from TRANCE modulators of the present invention, along with a pharmaceutically acceptable carrier. In particular, these pharmaceutical compositions of the present invention can be used to modulate the life span of mature dendritic cells in a mammal. Moreover, they can also be used  
25 to modulate T cell activation in a mammal, and hence immune response in a mammal. The present invention disclosed a pharmaceutical composition comprising a TRANCE agonist modulator, as described above, and a pharmaceutically acceptable carrier thereof. Moreover, the present invention discloses a pharmaceutical composition comprising a TRANCE antagonist modulator as  
30 described above, and a pharmaceutically acceptable carrier thereof.

It is a still further object of the present invention to provide a method to modulate immune response in a mammal, and in particular, to modulate the life span of mature dendritic cells in the mammal, and hence modulate T cell activation in the mammal. In one such method, a therapeutically effective amount of the

5 pharmaceutical composition comprising the TRANCE agonist modulator is administered to a mammal, along with an antigen. The antigen can be a virus, or a fragment thereof, a pathogen or a fragment thereof, or a tumor, or a fragment thereof. This method can be used to increase immune response against such an antigen. Hence, conditions such as a virus like an adenovirus or HIV can be treated

10 with this method. Moreover, cancer can be treated with this method.

Yet still another object of the present invention is to utilize the pharmaceutical composition invention containing a TRANCE antagonist modulator to treat an immune system related condition, such as autoimmune disease. This method

15 comprises administering to a mammal a therapeutically effective amount of the pharmaceutical composition having the TRANCE antagonist modulator. As a result, the life span of mature dendritic cells of the mammal, and hence its immune response, is decreased. Such a method can also be used to treat a mammal suffering from hypersensitivity to an allergen, whereby this method induces anergy

20 in the mammal towards the allergen.

Another object of the present invention is to provide a method of diagnosing an immune system related condition in a mammal. This method comprises assaying a bodily sample of mammal to determine whether TRANCE is expressed therein.

25 The bodily sample can be blood, or lymphoid tissue, such as lymph node, spleen or thymus tissue. The nucleic acids and antibodies of the present inventions have utility in such an assay.

Also, another object is the use of the present invention in a gene therapy method to

30 modulate the expression of TRANCE in the mammal. The method involves removing a hematopoietic stem cell from a mammal, and destroying all remaining

hematopoietic stem cells in the mammal. The stem cell removed is transfected with the expression vector of the present invention, and then reintroduced into the mammal. As a result, the animal will ultimately be repopulated with T cells which express TRANCE.

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Other objects and advantages will become apparent to those skilled in the art from a review of the ensuing description which proceeds with reference to the following illustrative drawings.

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### DESCRIPTION OF THE DRAWINGS

**FIGURE 1.** The cDNA nucleic acid molecule encoding human TRANCE (SEQ ID NO:1).

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**FIGURE 2.** The amino acid sequence of human TRANCE (SEQ ID NO:2).

**FIGURE 3.** The cDNA nucleic acid molecule encoding murine TRANCE (SEQ ID NO:3).

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**FIGURE 4.** The amino acid sequence of murine TRANCE (SEQ ID NO:4).

**FIGURE 5.** *Identification of a gene defective in KIT50.1.9.1.*

**FIGURE 5A.** Differential screening of the 8-50.51 gene fragment and Nur77 cDNA with probes from TCR-stimulated KMLs8.3.5.1 (KMLs8.3.5.1+) and TCR-stimulated KIT50.1.9.1 (KIT50.1.9.1+).

25

**FIGURE 5B.** Northern analysis of the TRANCE transcript in control, unstimulated (-) and TCR-stimulated (+) KMLs8.3.5.1 or KIT50.1.9.1 using 8-50.51 cDNA as a probe.

30 GAPDH was used as a control for poly A(+) RNA loading.

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1003910-1444

**FIGURE 6. Sequence analysis of the *TRANCE* gene.**

FIGURE 6A. The predicted amino acid sequence of the full length mouse *TRANCE* protein (m*TRANCE*) (SEQ ID NO:4) compared with the extracellular domain of human *TRANCE* (h*TRANCE*) (SEQ ID NO:2). Dots indicate shared identity  
 5 between the mouse and human protein and dashes indicate gaps between regions of homology. The transmembrane domain is underlined. Residues labeled with an asterisk (\*) indicate a potential *N*-linked glycosylation sites. The numbers in the left-hand column indicate the amino acid residue positions in the m*TRANCE* protein. Genbank accession numbers: m*TRANCE*, AF013170; h*TRANCE* (partial),  
 10 AF013171.

FIGURE 6B. Amino acid alignment of murine *TRANCE* (SEQ ID NO:4) with other murine members of the TNF cytokine gene family, such as mFasL (SEQ ID NO:5), mTRAIL (SEQ ID NO:6), mLT-Beta (SEQ ID NO:7), and mTNF-alpha (SEQ ID  
 15 NO:8). Bars represent the  $\beta$  sheets as estimated from the TNF crystal structure (31). Shaded residues are those that match the consensus sequence. The numbers in the left-hand column indicate the residue positions from the full length protein sequences. Dashes indicate gaps between regions of homology

**FIGURE 7. Expression and regulation of *TRANCE*.**

FIGURE 7A. Left: Effect of FK506 and cycloheximide (CHX) on TCR-induced upregulation of *TRANCE* and FasL by Northern analysis. T cell hybridomas were stimulated on  $\alpha$ -TCR Ab coated plates for the indicated amount of time in the presence of media alone (-), FK506 (10 ng/mL) or CHX (1  $\mu$ g/mL). Right: Northern  
 25 of *TRANCE* and FasL expression in LNTC stimulated with ConA + IL-2 or ConA + IL-2 +  $\alpha$ -CD3 $\epsilon$ . The blots were stripped and reprobed with GAPDH to normalize for the amount of loaded RNA.

FIGURE 7B. Left: Northern analysis of *TRANCE* in various mouse tissues. 28S  
 30 and 16S ribosomal RNA is indicated. Equal amounts of RNA were loaded as determined with a 28S ribosomal RNA probe (data not shown). Right: RT-PCR and

Southern blot analysis of TRANCE in T and B cell enriched populations.

Amplification of  $\beta$ -actin was used to control for the amount of RNA template used in the PCR reaction.

5 **FIGURE 8.** *Characterization of the recombinant TRANCE-Ecto protein.*

FIGURE 8A. SDS-PAGE and Coomassie Brilliant Blue staining of purified TRANCE-Ecto. Molecular weight markers are indicated on the left of the figure.

FIGURE 8B. JNK activation by TRANCE. Cells were purified as described in the

- 10 Materials and Methods and stimulated with 500 ng/mL of purified TRANCE-Ecto in 10% glycerol/PBS for the indicated amount of time on M2 coated plates. As a negative control, thymocytes were treated with an equivalent volume of a 10% glycerol/PBS solution on M2 coated plates (control). JNK activation was assessed by incorporation of  $^{32}$ P-ATP into purified GST-c-Jun(1-79). The band intensities were
- 15 quantified by phosphoimaging and presented as the fold induction over the unstimulated samples (0 min).

**FIGURE 9.** *TRANCE-R expression in various cell-types.* Cells were prepared as described in the *Materials and Methods* section of Example II, *infra.*, and stained with

20 10  $\mu$ g/mL of the hCD8-TRANCE recombinant protein (*solid lines*) or with secondary reagents alone (*dotted line*). Only viable cells as determined by PI exclusion were gated and analyzed for TRANCE-R expression. Fresh DC were analyzed by two-color staining after gating on CD11c<sup>high</sup> cells. Each staining was reproduced at least twice.

25 **FIGURE 10.** *TRANCE is a DC survival factor that upregulates Bcl-x<sub>L</sub>.*

FIGURE 10A. BMDC were cultured in complete medium in the presence or absence of recombinant TRANCE (1  $\mu$ g/mL) for 48 hours then visualized under an inverted light microscope.

- 30 FIGURE 10B. Duplicate wells containing  $3 \times 10^4$  BMDC were cultured with increasing doses of recombinant TRANCE in complete medium in flat-bottom 96-



well plates. The percentage of cell survival was assessed 48 h later by trypan blue exclusion. The average of three experiments, and the SEMs, are shown.

FIGURE 10C.  $3 \times 10^4$  BMDC were cultured in complete medium in the presence or  
 5 absence of recombinant TRANCE (1  $\mu\text{g/mL}$ ) or mCD8-CD40L (1/1000 of the culture supernatants). Cell viability was assessed daily by trypan blue exclusion. Representative data of three independent experiments are shown.

FIGURE 10D  $3 \times 10^4$  GM-CSF and IL-4 stimulated human monocyte-derived DC were  
 10 cultured for 2 days in monocyte conditioned medium (MCM) to generate mature DC (26). Thereafter, DCs were cultured in the presence or absence of recombinant TRANCE (1  $\mu\text{g/mL}$ ) and cell viability was assessed each day by trypan blue exclusion.

FIGURE 10E 50  $\mu\text{g}$  of protein extracted from BMDC cultured for 24 h as described in  
 15 Figure 2C were analyzed for Bcl-2 and Bcl-x<sub>L</sub> protein expression by western-blot analysis. Basal levels of Bcl-2 and Bcl-xL were determined in day 8 BMDC (0 hr).

**FIGURE 11. *Cell surface marker expression and T cell stimulatory function of TRANCE treated BMDC.***

20  
 FIGURE 11A.  $2.5 \times 10^3$  BMDC were cultured with increasing doses of TRANCE in a final volume of 100  $\mu\text{l}$  in triplicate in flat-bottom 96-well plates. After 48 hours  $10^5$  purified allogeneic T cells in 100  $\mu\text{l}$  were added in each well and  $^3\text{H}$ -Thymidine incorporation was assessed after 3 days of culture. One experiment of 3 are shown.

25  
 FIGURE 11B.  $2.5 \times 10^4$  BMDC were cultured in the presence of or the absence of TRANCE or CD40L for 48 h. After washing and counting the cells, dilutions of live cells were cultured with  $10^5$  purified allogeneic T cells and  $^3\text{H}$ -Thymidine incorporation was assessed after 3 days of culture.

30  
 FIGURE 11C. BMDC were cultured in complete medium for 24 h in the presence

(*solid lines*) or absence (*dotted lines*) of soluble FLAG-TRANCE (1  $\mu\text{g/mL}$ ) and analyzed for the indicated surface markers expression by FACS after gating the live cells. Similar results were obtained after 48 h of culture.

- 5 **FIGURE 12.** *TRANCE does not induce the proliferation of B Cells.* Triplicate wells of  $2 \times 10^4$  purified B cells were cultured in complete medium in the presence of increasing doses of soluble TRANCE or CD40L in flat-bottom 96 well plates.  $^3\text{[H]}$ -Thymidine incorporation was assessed after 2 days of culture.
- 10 **FIGURE 13.** *TRANCE-R signaling is dependent on TRAF2.* Thymocytes from transgenic mice expressing TRAF2.DN or control litter mates were stimulated with hCD8-TRANCE (1  $\mu\text{g/mL}$ ) on OKT8 (10  $\mu\text{g/mL}$ ) coated plates for the indicated amount of time then assayed for JNK activity. The degree JNK activation was analyzed on a phosphorimager (Molecular Imager System, Bio-Rad Laboratories, Hercules, CA) and plotted as fold induction over time 0. Representative results of three independent experiments are shown.

### DETAILED DESCRIPTION

- 20 As noted above, the present invention discloses an isolated nucleic acid molecules, or degenerate variants thereof, which encode TRANCE. Examples include an isolated nucleic acid molecule comprising a DNA sequence as set forth in Figure 1 (SEQ ID NO:1), or degenerate variants thereof. This molecule corresponds to an isolated nucleic acid molecule which encodes human TRANCE. Also disclosed herein is an
- 25 isolated nucleic acid molecule having a DNA sequence as set forth in Figure 3 (SEQ ID NO:3), or degenerate variants thereof, which corresponds to a isolated nucleic acid molecule which encodes murine TRANCE

- Moreover, nucleic acids hybridizable to an isolated nucleic acid molecule comprising
- 30 a DNA sequence as set forth in Figure 1 (SEQ ID NO:1) or Figure 3 (SEQ ID NO:3), or degenerate variants thereof, are also included in the present invention

Applicants have discovered that TRANCE is expressed on the surface of T cells, and that mature dendritic cells of the immune system have a surface receptor, TRANCE-R. When the T cell interacts with a mature dendritic cell presenting an antigen,

- 5 TRANCE interacts with TRANCE-R. This interaction causes an upregulation of the expression of Bcl-x<sub>L</sub> in the mature dendritic cell, which inhibits apoptosis. As a result, the life span of the mature dendritic cell is increased.

As used herein, the term "TRANCE" refers to an integral membrane bound protein on the surface of T cells, which has been described [Wong *et al.* *J. Bio. Chem* 10 272:25190-25194 (1997); this publication is specifically incorporated by reference in its entirety].

The term "TRANCE-R" refers to a TRANCE receptor located on the surface of 15 mature dendritic cells.

An "agonist" of TRANCE according to the invention is a compound that (i) binds to TRANCE-R on the surface of mature dendritic cells; and (ii) activates signal transduction with the mature dendritic cell such causing the upregulation of the 20 expression of Bcl-x<sub>L</sub> in the mature dendritic cell, which inhibits apoptosis in the cell. The activity of a TRANCE agonist can be evaluated *in vitro* by numerous methods, including, and by no means limited to, determining the life span of a mature dendritic cell exposed to the agonist and comparing it with the life span of a mature dendritic cell not exposed to the agonist. A TRANCE agonist is expected to increase the life 25 span of mature dendritic cells, and thus be useful in a treatment regimen for immune system related conditions, such as HIV or cancer.

An "antagonist" of TRANCE according to the invention is a compound that blocks TRANCE (or a TRANCE agonist) signal transduction. In one embodiment, the 30 antagonist is an anti-TRANCE antibody which binds to TRANCE on the surface of T cells, and prevents the interaction of TRANCE with TRANCE-R on the surface of

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mature dendritic cells. In another embodiment, the TRANCE antagonist is an anti-sense TRANCE nucleic acid comprising at least one phosphodiester analog bond. A TRANCE antagonist is expected to prevent the upregulation of expression of Bcl-x<sub>L</sub> in mature dendritic cells so that apoptosis is not inhibited in the cells. As a result, the life span of mature dendritic cells exposed to a TRANCE antagonist are decreased relative to the life span of mature dendritic cells which can interact with TRANCE. Moreover, this decrease in life span results in a decrease in T cell activation, and hence a decrease in immune response.

#### 10                    Isolated TRANCE Protein and Fragments thereof

Also included in the present invention are amino acid sequences of TRANCE or fragments thereof. In one embodiment of the present invention, TRANCE is a polypeptide comprising an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4) or conserved variants thereof. A polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or conserved variants thereof corresponds to human TRANCE, and a polypeptide comprising an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), conserved variants thereof.

#### Anti-TRANCE antibodies

20    The present invention also includes antibodies having TRANCE, or a fragment thereof, as an immunogen.

An "antibody" is any immunoglobulin, including antibodies and fragments thereof, that binds a specific epitope. The term encompasses polyclonal, monoclonal, and chimeric antibodies. the last mentioned described in further detail in U.S. Patent Nos. 4,816,397 and 4,816,567.

An "antibody combining site" is that structural portion of an antibody molecule comprised of heavy and light chain variable and hypervariable regions that specifically binds antigen.

The phrase "antibody molecule" in its various grammatical forms as used herein contemplates both an intact immunoglobulin molecule and an immunologically active portion of an immunoglobulin molecule.

- 5 Exemplary antibody molecules are intact immunoglobulin molecules, substantially intact immunoglobulin molecules and those portions of an immunoglobulin molecule that contains the paratope, including those portions known in the art as Fab, Fab', F(ab')<sub>2</sub> and F(v), which portions are preferred for use in the therapeutic methods described herein.

10

- Fab and F(ab')<sub>2</sub> portions of antibody molecules are prepared by the proteolytic reaction of papain and pepsin, respectively, on substantially intact antibody molecules by methods that are well-known. See for example, U.S. Patent No. 4,342,566 to Theofilopolous et al. Fab' antibody molecule portions are also well-known and are  
 15 produced from F(ab')<sub>2</sub> portions followed by reduction of the disulfide bonds linking the two heavy chain portions as with mercaptoethanol, and followed by alkylation of the resulting protein mercaptan with a reagent such as iodoacetamide. An antibody containing intact antibody molecules is preferred herein.

- 20 The phrase "monoclonal antibody" in its various grammatical forms refers to an antibody having only one species of antibody combining site capable of immunoreacting with a particular antigen. A monoclonal antibody thus typically displays a single binding affinity for any antigen with which it immunoreacts. A monoclonal antibody may therefore contain an antibody molecule having a plurality  
 25 of antibody combining sites, each immunospecific for a different antigen; e.g., a bispecific (chimeric) monoclonal antibody.

- Moreover, the antibodies to TRANCE included in the present invention are detectably labeled in order permit their use in numerous diagnostic assays, such as  
 30 immunoassays, which are explained herein. Such detectable labels include, but are not limited to, conjugation of the TRANCE antibody to alkaline phosphatase,

peroxidase, or the integration of radioactive isotopes into the structure of the antibody.

Expression of TRANCE in expression vectors of the present invention

- 5 According to the present invention, unicellular hosts can be transfected with an expression vector of the present invention. An expression vector of the present invention can comprise an isolated nucleic acid molecule encoding TRANCE, or degenerate variants thereof, operatively associated with a promoter. Such cells can be used to produce TRANCE for use in the elucidation of the molecular genetics of the
- 10 TRANCE gene, and in the treatment of immune system related conditions.

- An isolated nucleic acid molecule comprising a DNA sequence as set forth in Figure 1 (SEQ ID NO:1), Figure 3 (SEQ ID NO:3), or degenerate variants thereof, or an isolated nucleic acid molecule which is hybridizable to an isolated nucleic acid
- 15 comprising a DNA sequence as set forth in Figure 1 (SEQ ID NO:1), Figure 3 (SEQ ID NO:3) or degenerate variants thereof, under standard hybridization conditions, can also be used in an expression vector of the present invention.

- In accordance with the present invention there may be employed conventional
- 20 molecular biology, microbiology, and recombinant DNA techniques within the skill of the art. Such techniques are explained fully in the literature. See, e.g., Sambrook, Fritsch & Maniatis, *Molecular Cloning: A Laboratory Manual*, Second Edition (1989) Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York (herein "Sambrook et al., 1989"); *DNA Cloning: A Practical Approach*, Volumes I and II
- 25 (D.N. Glover ed. 1985); *Oligonucleotide Synthesis* (M.J. Gait ed. 1984); *Nucleic Acid Hybridization* [B.D. Hames & S.J. Higgins eds. (1985)]; *Transcription And Translation* [B.D. Hames & S.J. Higgins. eds. (1984)]; *Animal Cell Culture* [R.I. Freshney, ed. (1986)]; *Immobilized Cells And Enzymes* [IRL Press, (1986)]; B. Perbal, *A Practical Guide To Molecular Cloning* (1984); F.M. Ausubel et al. (eds.), *Current*
- 30 *Protocols in Molecular Biology*, John Wiley & Sons, Inc. (1994).

Therefore, if appearing herein, the following terms shall have the definitions set out below.

- A "vector" is a replicon, such as plasmid, phage or cosmid, to which another DNA  
 5 segment may be attached so as to bring about the replication of the attached segment. A "replicon" is any genetic element (*e.g.*, plasmid, chromosome, virus) that functions as an autonomous unit of DNA replication *in vivo*, *i.e.*, capable of replication under its own control.
- 10 A "cassette" refers to a segment of DNA that can be inserted into a vector at specific restriction sites. The segment of DNA encodes a polypeptide of interest, and the cassette and restriction sites are designed to ensure insertion of the cassette in the proper reading frame for transcription and translation.
- 15 A cell has been "transfected" by exogenous or heterologous DNA when such DNA has been introduced inside the cell. A cell has been "transformed" by exogenous or heterologous DNA when the transfected DNA effects a phenotypic change. Preferably, the transforming DNA should be integrated (covalently linked) into chromosomal DNA making up the genome of the cell.
- 20 "Heterologous" DNA refers to DNA not naturally located in the cell, or in a chromosomal site of the cell. Preferably, the heterologous DNA includes a gene foreign to the cell.
- 25 A "nucleic acid molecule" refers to the phosphate ester polymeric form of ribonucleosides (adenosine, guanosine, uridine or cytidine; "RNA molecules") or deoxyribonucleosides (deoxyadenosine, deoxyguanosine, deoxythymidine, or deoxycytidine; "DNA molecules"), or any phosphoester analogs thereof, such as phosphorothioates and thioesters, in either single stranded form, or a double-stranded  
 30 helix. Double stranded DNA-DNA, DNA-RNA and RNA-RNA helices are possible. The term nucleic acid molecule, and in particular DNA or RNA molecule, refers only

to the primary and secondary structure of the molecule, and does not limit it to any particular tertiary forms. Thus, this term includes double-stranded DNA found, *inter alia*, in linear or circular DNA molecules (e.g., restriction fragments), plasmids, and chromosomes. In discussing the structure of particular double-stranded DNA

5 molecules, sequences may be described herein according to the normal convention of giving only the sequence in the 5' to 3' direction along the nontranscribed strand of DNA (*i.e.*, the strand having a sequence homologous to the mRNA). A "recombinant DNA molecule" is a DNA molecule that has undergone a molecular biological manipulation.

10

A DNA sequence is "operatively associated" to an expression control sequence when the expression control sequence controls and regulates the transcription and translation of that DNA sequence. The term "operatively associated" includes having an appropriate start signal (e.g., ATG) in front of the DNA sequence to be expressed and maintaining the correct reading frame to permit expression of the DNA sequence

15 under the control of the expression control sequence and production of the desired product encoded by the DNA sequence. If a gene that one desires to insert into a recombinant DNA molecule does not contain an appropriate start signal, such a start signal can be inserted in front of the gene.

20

A nucleic acid molecule is "hybridizable" to another nucleic acid molecule, such as a cDNA, genomic DNA, or RNA, when a single stranded form of the nucleic acid molecule can anneal to the other nucleic acid molecule under the appropriate conditions of temperature and solution ionic strength (*see* Sambrook et al., *supra*).

25 The conditions of temperature and ionic strength determine the "stringency" of the hybridization. For preliminary screening for homologous nucleic acids, low stringency hybridization conditions, corresponding to a  $T_m$  of 55°, can be used, *e.g.*, 5x SSC, 0.1% SDS, 0.25% milk, and no formamide; or 30% formamide, 5x SSC, 0.5% SDS). Moderate stringency hybridization conditions correspond to a higher  $T_m$ ,

30 *e.g.*, 40% formamide, with 5x or 6x SCC. High stringency hybridization conditions correspond to the highest  $T_m$ , *e.g.*, 50% formamide, 5x or 6x SCC. Hybridization



requires that the two nucleic acids contain complementary sequences, although depending on the stringency of the hybridization, mismatches between bases are possible. The appropriate stringency for hybridizing nucleic acids depends on the length of the nucleic acids and the degree of complementation, variables well known in the art. The greater the degree of similarity or homology between two nucleotide sequences, the greater the value of  $T_m$  for hybrids of nucleic acids having those sequences. The relative stability (corresponding to higher  $T_m$ ) of nucleic acid hybridizations decreases in the following order: RNA:RNA, DNA:RNA, DNA:DNA. For hybrids of greater than 100 nucleotides in length, equations for calculating  $T_m$  have been derived (see Sambrook et al., *supra*, 9.50-9.51). For hybridization with shorter nucleic acids, *i.e.*, oligonucleotides, the position of mismatches becomes more important, and the length of the oligonucleotide determines its specificity (see Sambrook et al., *supra*, 11.7-11.8). Preferably a minimum length for a hybridizable nucleic acid is at least about 10 nucleotides; preferably at least about 20 nucleotides; and more preferably the length is at least about 30 nucleotides.

The term "standard hybridization conditions" refers to salt and temperature conditions substantially equivalent to 5 x SSC and 65°C for both hybridization and wash. However, one skilled in the art will appreciate that such "standard hybridization conditions" are dependent on particular conditions including the concentration of sodium and magnesium in the buffer, nucleotide sequence length and concentration, percent mismatch, percent formamide, and the like. Also important in the determination of "standard hybridization conditions" is whether the two sequences hybridizing are RNA-RNA, DNA-DNA or RNA-DNA. Such standard hybridization conditions are easily determined by one skilled in the art according to well known formulae, wherein hybridization is typically 10-20°C below the predicted or determined  $T_m$  with washes of higher stringency, if desired.

"Homologous recombination" refers to the insertion of a foreign DNA sequence of a vector in a chromosome. Preferably, the vector targets a specific chromosomal site for homologous recombination. For specific homologous recombination, the vector

will contain sufficiently long regions of homology to sequences of the chromosome to allow complementary binding and incorporation of the vector into the chromosome. Longer regions of homology, and greater degrees of sequence similarity, may increase the efficiency of homologous recombination.

5

A DNA "coding sequence" is a double-stranded DNA sequence which is transcribed and translated into a polypeptide in a cell *in vitro* or *in vivo* when placed under the control of appropriate regulatory sequences. The boundaries of the coding sequence are determined by a start codon at the 5' (amino) terminus and a translation stop

10 codon at the 3' (carboxyl) terminus. A coding sequence can include, but is not limited to, prokaryotic sequences, cDNA from eukaryotic mRNA, genomic DNA sequences from eukaryotic (*e.g.*, mammalian) DNA, and even synthetic DNA sequences. If the coding sequence is intended for expression in a eukaryotic cell, a polyadenylation signal and transcription termination sequence will usually be located 3' to the coding  
15 sequence.

Transcriptional and translational control sequences are DNA regulatory sequences, such as promoters, enhancers, terminators, and the like, that provide for the expression of a coding sequence in a host cell. In eukaryotic cells, polyadenylation signals are

20 control sequences.

A "promoter" is a DNA regulatory region capable of binding RNA polymerase in a cell and initiating transcription of a downstream (3' direction) coding sequence. For purposes of defining the present invention, the promoter sequence is bounded at its 3' terminus by the transcription initiation site and extends upstream (5' direction) to  
25 include the minimum number of bases or elements necessary to initiate transcription at levels detectable above background. Within the promoter sequence will be found a transcription initiation site (conveniently defined for example, by mapping with nuclease S1), as well as protein binding domains (consensus sequences) responsible  
30 for the binding of RNA polymerase.

A coding sequence is "under the control" of transcriptional and translational control sequences in a cell when RNA polymerase transcribes the coding sequence into mRNA, which is then trans-RNA spliced and translated into the protein encoded by the coding sequence.

5

A "signal sequence" is included at the beginning of the coding sequence of a protein to be expressed on the surface of a cell. This sequence encodes a signal peptide, N-terminal to the mature polypeptide, that directs the host cell to translocate the polypeptide. The term "translocation signal sequence" is used herein to refer to this sort of signal sequence. Translocation signal sequences can be found associated with a variety of proteins native to eukaryotes and prokaryotes, and are often functional in both types of organisms.

As used herein, the term "sequence homology" in all its grammatical forms refers to the relationship between proteins that possess a "common evolutionary origin," including proteins from superfamilies (*e.g.*, the immunoglobulin superfamily) and homologous proteins from different species (*e.g.*, myosin light chain, etc.) (Reeck et al., 1987, Cell 50:667).

Accordingly, the term "sequence similarity" in all its grammatical forms refers to the degree of identity or correspondence between nucleic acid or amino acid sequences of proteins that do not share a common evolutionary origin (*see* Reeck et al., *supra*). However, in common usage and in the instant application, the term "homologous," when modified with an adverb such as "highly," may refer to sequence similarity and not a common evolutionary origin.

In a specific embodiment, two DNA sequences are "substantially homologous" or "substantially similar" when at least about 50% (preferably at least about 75%, and most preferably at least about 90 or 95%) of the nucleotides match over the defined length of the DNA sequences. Sequences that are substantially homologous can be identified by comparing the sequences using standard software available in sequence

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data banks. or in a Southern hybridization experiment under, for example, stringent conditions as defined for that particular system. Defining appropriate hybridization conditions is within the skill of the art. See, e.g., Maniatis et al., *supra*; DNA Cloning. Vols. I & II, *supra*; Nucleic Acid Hybridization, *supra*.

5

Similarly, in a particular embodiment, two amino acid sequences are "substantially homologous" or "substantially similar" when greater than 30% of the amino acids are identical, or greater than about 60% are similar (functionally identical). Preferably, the similar or homologous sequences are identified by alignment using, for example,  
10 the GCG (Genetics Computer Group, Program Manual for the GCG Package, *Version* 7, Madison, Wisconsin) pileup program.

The term "corresponding to" is used herein to refers to similar or homologous sequences, whether the exact position is identical or different from the molecule to  
15 which the similarity or homology is measured. Thus, the term "corresponding to" refers to the sequence similarity, and not the numbering of the amino acid residues or nucleotide bases.

A gene encoding TRANCE, whether genomic DNA or cDNA, can be isolated from  
20 any source. particularly from a human cDNA or genomic library. Methods for obtaining these genes are well known in the art, as described above (*see, e.g.,* Sambrook et al., 1989, *supra*). Accordingly, any animal cell potentially can serve as the nucleic acid source for the molecular cloning of these genes. The DNA may be obtained by standard procedures known in the art from cloned DNA (*e.g.,* a DNA  
25 "library"), and preferably is obtained from a cDNA library prepared from tissues with high level expression of the protein (*e.g.,* a T cell cDNA library, since these are the cells that evidence highest levels of expression of TRANCE), by chemical synthesis, by cDNA cloning, or by the cloning of genomic DNA, or fragments thereof, purified from the desired cell (See, for example, Sambrook et al., 1989, *supra*; Glover, D.M.  
30 (ed.), 1985, DNA Cloning: A Practical Approach, MRL Press, Ltd., Oxford, U.K. Vol. I, II). Clones derived from genomic DNA may contain regulatory and intron

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DNA regions in addition to coding regions; clones derived from cDNA will not contain intron sequences. Whatever the source, the gene should be molecularly cloned into a suitable vector for propagation of the gene.

- 5 Moreover, the promoter of the expression vector of the present invention can also includes immediate early promoters of hCMV, early promoters of SV40, early promoters of adenovirus, early promoters of vaccinia, early promoters of polyoma, late promoters of SV40, late promoters of adenovirus, late promoters of vaccinia, late promoters of polyoma, the *lac* the *trp* system, the *TAC* system, the *TRC* system, the  
 10 major operator and promoter regions of phage lambda, control regions of coat protein, 3-phosphoglycerate kinase promoter, acid phosphatase promoter, or promoters of yeast  $\alpha$  mating factor.

- The necessary transcriptional and translational signals can be provided on a  
 15 recombinant expression vector, or they may be supplied by the native gene encoding a TRANCE and/or its flanking regions.

- Expression elements of vectors vary in their strengths and specificities. Depending on the host-vector system utilized, any one of a number of suitable transcription and  
 20 translation elements may be used.

- TRANCE proteins of the invention, or analogs, derivatives, or fusion proteins thereof, may be expressed chromosomally, after integration of the coding sequence by recombination. In this regard, any of a number of amplification systems may be used  
 25 to achieve high levels of stable gene expression (*See* Sambrook et al., 1989, *supra*).

- A unicellular host into which the recombinant vector or vectors comprising the nucleic acid encoding TRANCE is cultured in an appropriate cell culture medium under conditions that provide for expression of the TRANCE by the cell. In one  
 30 embodiment of the present invention, a nucleic acid encoding a TRANCE fusion gene is expressed in a baculovirus expression system as a fusion protein, wherein the

extracellular domain of murine TRANCE (amino acid residues 245-316 of Figure 4 (SEQ ID NO:4)) was fused to human CD8 $\alpha$ .

Any of the methods for the insertion of DNA fragments into a cloning vector may be used to construct expression vectors containing a gene consisting of appropriate transcriptional/translational control signals and the protein coding sequences. These methods may include *in vitro* recombinant DNA and synthetic techniques and *in vivo* recombination (genetic recombination).

As is well known in the art, DNA sequences may be expressed by operatively linking them to an expression control sequence in an appropriate expression vector and employing that expression vector to transform an appropriate unicellular host.

Such operative linking of a DNA sequence of this invention to an expression control sequence, of course, includes, if not already part of the DNA sequence, the provision of an initiation codon, ATG, in the correct reading frame upstream of the DNA sequence.

Expression of a TRANCE protein may be controlled by promoter/enhancer elements disclosed herein, but these regulatory elements must be functional in the unicellular host selected for expression. Promoters which may be used to control gene expression include, but are not limited to, the SV40 early promoter region (Benoist and Chambon, 1981, Nature 290:304-310), the promoter contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto, et al., 1980, Cell 22:787-797), the herpes thymidine kinase promoter (Wagner et al., 1981, Proc. Natl. Acad. Sci. U.S.A. 78:1441-1445), the regulatory sequences of the metallothionein gene (Brinster et al., 1982, Nature 296:39-42); prokaryotic expression vectors such as the  $\beta$ -lactamase promoter (Villa-Kamaroff, et al., 1978, Proc. Natl. Acad. Sci. U.S.A. 75:3727-3731), or the *tac* promoter (DeBoer, et al., 1983, Proc. Natl. Acad. Sci. U.S.A. 80:21-25); see also "Useful proteins from recombinant bacteria" in Scientific American. 1980. 242:74-94; promoter elements from yeast or other fungi such as the Gal 4 promoter,

- the ADC (alcohol dehydrogenase) promoter, PGK (phosphoglycerol kinase) promoter, alkaline phosphatase promoter; and the animal transcriptional control regions, which exhibit tissue specificity and have been utilized in transgenic animals: elastase I gene control region which is active in pancreatic acinar cells (Swift et al., 1984, Cell
- 5 38:639-646; Ornitz et al., 1986, Cold Spring Harbor Symp. Quant. Biol. 50:399-409; MacDonald, 1987, Hepatology 7:425-515); insulin gene control region which is active in pancreatic beta cells (Hanahan, 1985, Nature 315:115-122), immunoglobulin gene control region which is active in lymphoid cells (Grosschedl et al., 1984, Cell 38:647-658; Adames et al., 1985, Nature 318:533-538; Alexander et al., 1987, Mol. Cell.
- 10 Biol. 7:1436-1444), mouse mammary tumor virus control region which is active in testicular, breast, lymphoid and mast cells (Leder et al., 1986, Cell 45:485-495), albumin gene control region which is active in liver (Pinkert et al., 1987, Genes and Devel. 1:268-276), alpha-fetoprotein gene control region which is active in liver (Krumlauf et al., 1985, Mol. Cell. Biol. 5:1639-1648; Hammer et al., 1987, Science
- 15 235:53-58), alpha 1-antitrypsin gene control region which is active in the liver (Kelsey et al., 1987, Genes and Devel. 1:161-171), beta-globin gene control region which is active in myeloid cells (Mogam et al., 1985, Nature 315:338-340; Kollias et al., 1986, Cell 46:89-94), myelin basic protein gene control region which is active in oligodendrocyte cells in the brain (Readhead et al., 1987, Cell 48:703-712), myosin
- 20 light chain-2 gene control region which is active in skeletal muscle (Sani, 1985, Nature 314:283-286), and gonadotropic releasing hormone gene control region which is active in the hypothalamus (Mason et al., 1986, Science 234:1372-1378).

- Mammalian expression vectors contemplated for use in the invention include vectors
- 25 with inducible promoters, such as the dihydrofolate reductase (DHFR) promoter, *e.g.*, any expression vector with a *DHFR* expression vector, or a *DHFR*/methotrexate co-amplification vector, such as pED (*Pst*I, *Sal*I, *Sba*I, *Sma*I, and *Eco*RI cloning site, with the vector expressing both the cloned gene and *DHFR*; see Kaufman, *Current Protocols in Molecular Biology*, 16.12 (1991). Alternatively, a glutamine
- 30 synthetase/methionine sulfoximine co-amplification vector, such as pEE14 (*Hind*III, *Xba*I, *Sma*I, *Sba*I, *Eco*RI, and *Bcl*I cloning site, in which the vector expresses

glutamine synthase and the cloned gene: Celltech). In another embodiment, a vector that directs episomal expression under control of Epstein Barr Virus (EBV) can be used, such as pREP4 (*Bam*HI, *Sfi*I, *Xho*I, *Not*I, *Nhe*I, *Hind*III, *Nhe*I, *Pvu*II, and *Kpn*I cloning site, constitutive RSV-LTR promoter, hygromycin selectable marker;

- 5 Invitrogen), pCEP4 (*Bam*HI, *Sfi*I, *Xho*I, *Not*I, *Nhe*I, *Hind*III, *Nhe*I, *Pvu*II, and *Kpn*I cloning site, constitutive hCMV immediate early gene, hygromycin selectable marker; Invitrogen), pMEP4 (*Kpn*I, *Pvu*I, *Nhe*I, *Hind*III, *Not*I, *Xho*I, *Sfi*I, *Bam*HI cloning site, inducible methallothionein IIa gene promoter, hygromycin selectable marker; Invitrogen), pREP8 (*Bam*HI, *Xho*I, *Not*I, *Hind*III, *Nhe*I, and *Kpn*I cloning site, RSV-  
10 LTR promoter, histidinol selectable marker; Invitrogen), pREP9 (*Kpn*I, *Nhe*I, *Hind*III, *Not*I, *Xho*I, *Sfi*I, and *Bam*HI cloning site, RSV-LTR promoter, G418 selectable marker; Invitrogen), and pEBVHis (RSV-LTR promoter, hygromycin selectable marker, N-terminal peptide purifiable via ProBond resin and cleaved by enterokinase; Invitrogen). Selectable mammalian expression vectors for use in the invention  
15 include pRc/CMV (*Hind*III, *Bst*XI, *Not*I, *Sba*I, and *Apa*I cloning site, G418 selection; Invitrogen), pRc/RSV (*Hind*III, *Spe*I, *Bst*XI, *Not*I, *Xba*I cloning site, G418 selection; Invitrogen), and others. Vaccinia virus mammalian expression vectors (*see*, Kaufman, 1991, *supra*) for use according to the invention include but are not limited to pSC11 (*Sma*I cloning site, TK- and  $\beta$ -gal selection), pMJ601 (*Sal*I, *Sma*I, *Afl*I, *Nar*I, *Bsp*MII, *Bam*HI, *Apa*I, *Nhe*I, *Sac*II, *Kpn*I, and *Hind*III cloning site; TK- and  $\beta$ -gal selection),  
20 and pTKgptF1S (*Eco*RI, *Pst*I, *Sal*I, *Acc*I, *Hind*II, *Sba*I, *Bam*HI, and *Hpa*I cloning site, TK or XPRT selection).

- Once a particular recombinant DNA molecule is identified and isolated, several  
25 methods known in the art may be used to propagate it. Moreover, once a suitable host system and growth conditions are established, recombinant expression vectors of the present invention can be propagated and prepared in quantity. As previously explained, the expression vectors which can be used include, but are not limited to, the following vectors or their derivatives: human or animal viruses such as vaccinia  
30 virus or adenovirus; and plasmid and cosmid DNA vectors, to name but a few.



In addition, a unicellular host cell strain may be chosen which modulates the expression of the inserted sequences, or modifies and processes the gene product in the specific fashion desired. Different host cells have characteristic and specific mechanisms for the translational and post-translational processing and modification (e.g., glycosylation, cleavage [e.g., of signal sequence]) of proteins. Unicellular host cells of the present invention, include, but are not limited to *E. coli*, Pseudomonas, Bacillus, Streptomyces, yeast, CHO, R1.1, B-W, L-M, COS1, COS7, BSC1, BSC40, BMT10 and Sf9 cells.

- 10 Appropriate cell lines or host systems can be chosen to ensure the desired modification and processing of the foreign protein expressed. Expression in eukaryotic cells can increase the likelihood of "native" glycosylation and folding of a heterologous protein. Moreover, expression in mammalian cells can provide a tool for reconstituting, or constituting, TRANCE activity. Furthermore, different vector/host expression systems may affect processing reactions, such as proteolytic cleavages, to a different extent.

Vectors are introduced into desired host cells by methods known in the art, e.g., transfection, electroporation, microinjection, transduction, cell fusion. DEAE dextran, calcium phosphate precipitation, lipofection (lysosome fusion), use of a gene gun, or a DNA vector transporter (see, e.g., Wu et al., 1992, J. Biol. Chem. 267:963-967; Wu and Wu, 1988, J. Biol. Chem. 263:14621-14624; Hartmut et al., Canadian Patent Application No. 2,012,311, filed March 15, 1990).

- 25 A method for producing TRANCE, wherein the method is included in the present invention, comprises culturing a unicellular host under conditions that provide for expression of TRANCE, and recovering TRANCE from the unicellular host and the culture.

### 30 A modulator of Immune Response

Also disclosed herein is a modulator of immune response in a mammal, wherein the

modulator is selected from the group consisting of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, a fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, an antibody having an immunogen selected from the group consisting of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, a fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof, and an anti-sense TRANCE nucleic acid comprising at least one phosphodiester analog bond.

There are two types of modulators disclosed herein. One type is an agonist of TRANCE. It is expected to increase the active life of mature dendritic cells relative to the life of mature dendritic cells not exposed to this modulator, and hence increases T cell activation and overall immune response in the mammal. This type of modulator is selected from the group consisting of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, a fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof.

The other type of modulator is an antagonist of TRANCE. It is expected to prevent the interaction of TRANCE with TRANCE-R and decrease the active life of mature

dendritic cells relative to the life of mature dendritic cells which can interact with TRANCE. Hence, a TRANCE antagonist modulator decreases T cell activation and overall immune response in the mammal. This type of modulator is selected from the group consisting of an anti-sense TRANCE nucleic acid comprising at least one  
5 phosphodiester analog bond, and the antibody having an immunogen selected from the group consisting of a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants  
10 thereof, or a fragment thereof, a fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof.

The modulator of present invention also relates to genes encoding analogs or  
15 derivatives of TRANCE, that have the same or homologous functional activity as the native TRANCE and homologs thereof from other species. The production and use of derivatives and analogs or derivatives related to TRANCE are within the scope of the present invention. In one embodiment, the derivative or analog is functionally active, *i.e.*, capable of exhibiting one or more functional activities associated with a wild-type  
20 TRANCE of the invention. In another embodiment, the modulator is an analog or derivative of a TRANCE fusion protein, which contains protein domains from at least one specific protein in a construct.

TRANCE analogs or derivatives can be made by altering encoding nucleic acid  
25 sequences which encode TRANCE, by substitutions, additions or deletions that provide for functionally equivalent molecules. Preferably, derivatives are made that have enhanced or increased functional activity relative to that of native TRANCE.

Due to the degeneracy of nucleotide coding sequences, other DNA sequences which  
30 encode substantially the same amino acid sequence as genomic or cDNA TRANCE can be used in the practice of the present invention. These include but are not limited

to allelic genes, homologous genes from other species, and nucleotide sequences comprising all or portions of the genes which are altered by the substitution of different codons that encode the same amino acid within the sequence, thus producing a silent change. Likewise, the TRANCE analogs or derivatives of the invention include, but are not limited to, those containing, as a primary amino acid sequence, all or part of the amino acid sequence set forth in Figure 2 (SEQ ID NO:2) or Figure 4 (SEQ ID NO:4), including altered sequences in which functionally equivalent amino acids are substituted for s within these sequences resulting in a conservative amino acid substitution. For example, one or more amino acids within these sequences can be substituted by another amino acid of a similar polarity, which acts as a functional equivalent, resulting in a silent alteration. Substitutes for an amino acid within these sequences may be selected from other members of the class to which the amino acid belongs. For example, the nonpolar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine, proline, phenylalanine, tryptophan and methionine. Amino acids containing aromatic ring structures are phenylalanine, tryptophan, and tyrosine. The polar neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, asparagine, and glutamine. The positively charged (basic) amino acids include arginine, lysine and histidine. The negatively charged (acidic) amino acids include aspartic acid and glutamic acid. Such alterations will not be expected to affect apparent molecular weight as determined by polyacrylamide gel electrophoresis, or isoelectric point.

Particularly preferred substitutions are:

- Lys for Arg and vice versa such that a positive charge may be maintained;
- Glu for Asp and vice versa such that a negative charge may be maintained;
- Ser for Thr such that a free -OH can be maintained; and
- Gln for Asn such that a free  $\text{NH}_2$  can be maintained.

Amino acid substitutions may also be introduced to substitute an amino acid with a particularly preferable property. For example, a Cys may be introduced a potential site for disulfide bridges with another Cys. A His may be introduced as a particularly

"catalytic" site (*i.e.*, His can act as an acid or base and is the most common amino acid in biochemical catalysis). Pro may be introduced because of its particularly planar structure, which induces  $\beta$ -turns in the protein's structure.

- 5 The isolated nucleic acid sequence encoding TRANCE, or an analog or derivative thereof can be produced by various methods known in the art. The manipulations which result in their production can occur at the gene or protein level. For example, the cloned gene sequence can be modified by any of numerous strategies known in the art (Sambrook et al., 1989, *supra*). The sequence can be cleaved at appropriate sites
- 10 with restriction endonuclease(s), followed by further enzymatic modification if desired, isolated, and ligated *in vitro*. In the production of the gene encoding a derivative or analog, care should be taken to ensure that the modified gene remains within the same translational reading frame as the native gene, uninterrupted by translational stop signals, in the gene region where the desired activity is encoded.
- 15 Additionally, a nucleic acid sequence can be mutated *in vitro* or *in vivo*, to create and/or destroy translation, initiation, and/or termination sequences, or to create variations in coding regions and/or form new restriction endonuclease sites or destroy preexisting ones, to facilitate further *in vitro* modification. Preferably, such mutations
- 20 enhance the functional activity of the mutated gene product. Any technique for mutagenesis known in the art can be used, including but not limited to, *in vitro* site-directed mutagenesis (Hutchinson, C., et al., 1978, J. Biol. Chem. 253:6551; Zoller and Smith, 1984, DNA 3:479-488; Oliphant et al., 1986, Gene 44:177; Hutchinson et al., 1986, Proc. Natl. Acad. Sci. U.S.A. 83:710), use of "TAB" linkers (Pharmacia),
- 25 etc. PCR techniques are preferred for site directed mutagenesis (see Higuchi, 1989, "Using PCR to Engineer DNA", in *PCR Technology: Principles and Applications for DNA Amplification*, H. Erlich, ed., Stockton Press, Chapter 6, pp. 61-70).

Moreover, the present invention also includes derivatives or analogs of TRANCE

- 30 produced from a chemical modification. The TRANCE protein of the present invention may be derivatized by the attachment of one or more chemical moieties to

the protein moiety. The chemically modified derivatives may be further formulated for intraarterial, intraperitoneal, intramuscular, subcutaneous, intravenous, oral, nasal, pulmonary, topical or other routes of administration. Chemical modification of TRANCE may provide additional advantages under certain circumstances, such as

5 increasing the stability and circulation time of the chemically modified TRANCE and decreasing immunogenicity. See U.S. Patent No. 4,179,337, Davis et al., issued December 18, 1979. For a review, see Abuchowski et al., in *Enzymes as Drugs* (J.S. Holcerberg and J. Roberts, eds. pp. 367-383 (1981)). A review article describing protein modification and fusion proteins is Francis, 1992, *Focus on Growth Factors*

10 3:4-10, Mediscript: Mountview Court, Friern Barnet Lane, London N20, OLD, UK.

*Chemical Moieties For Derivatization.* The chemical moieties suitable for derivatization may be selected from among water soluble polymers. The polymer selected should be water soluble so that the TRANCE analog or derivative does not

15 precipitate in an aqueous environment, such as a physiological environment. Preferably, for therapeutic use of the end-product preparation, the polymer will be pharmaceutically acceptable. One skilled in the art will be able to select the desired polymer based on such considerations as whether the polymer/component conjugate will be used therapeutically, and if so, the desired dosage, circulation time, resistance

20 to proteolysis, and other considerations. For TRANCE, these may be ascertained using the assays provided herein.

The water soluble polymer may be selected from the group consisting of, for example, polyethylene glycol, copolymers of ethylene glycol/propylene glycol,

25 carboxymethylcellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone, poly-1, 3-dioxolane, poly-1,3,6-trioxane, ethylene/maleic anhydride copolymer, polyaminoacids (either homopolymers or random copolymers), and dextran or poly(n-vinyl pyrrolidone)polyethylene glycol, propylene glycol homopolymers, polypropylene oxide/ethylene oxide co- polymers, polyoxyethylated polyols and

30 polyvinyl alcohol. Polyethylene glycol propionaldehyde may have advantages in manufacturing due to its stability in water.



acid residue. Sulfhydryl groups may also be used as a reactive group for attaching the polyethylene glycol molecule(s). Preferred for therapeutic purposes is attachment at an amino group, such as attachment at the N-terminus or lysine group.

- 5 One may specifically desire N-terminally chemically modified TRANCE. Using polyethylene glycol as an illustration of the present compositions, one may select from a variety of polyethylene glycol molecules (by molecular weight, branching, etc.), the proportion of polyethylene glycol molecules to TRANCE molecules in the reaction mix, the type of pegylation reaction to be performed, and the method of
- 10 obtaining the selected N-terminally pegylated protein. The method of obtaining the N-terminally pegylated preparation (i.e., separating this moiety from other monopegylated moieties if necessary) may be by purification of the N-terminally pegylated material from a population of pegylated protein molecules. Selective N-terminal chemically modification may be accomplished by reductive alkylation
- 15 which exploits differential reactivity of different types of primary amino groups (lysine versus the N-terminal) available for derivatization in TRANCE. Under the appropriate reaction conditions, substantially selective derivatization of TRANCE at the N-terminus with a carbonyl group containing polymer is achieved. For example, one may selectively N-terminally pegylate TRANCE by performing the reaction at pH
- 20 which allows one to take advantage of the  $pK_a$  differences between the  $\epsilon$ -amino groups of the lysine residues and that of the  $\alpha$ -amino group of the N-terminal residue of TRANCE. By such selective derivatization attachment of a water soluble polymer to TRANCE is controlled: the conjugation with the polymer takes place predominantly at the N-terminus of TRANCE and no significant modification of other
- 25 reactive groups, such as the lysine side chain amino groups, occurs. Using reductive alkylation, the water soluble polymer may be of the type described above, and should have a single reactive aldehyde for coupling to TRANCE. Polyethylene glycol propionaldehyde, containing a single reactive aldehyde, may be used.
- 30 Also included in the modulator of the present invention is a fusion protein wherein its amino acid sequence contains an amino acid sequence as set forth in Figure 2 (SEQ



ID NO:2). Figure 4 (SEQ ID NO:4), conserved variants, or a fragment thereof. Fusion proteins are the product of a nucleic acid created by the fusion of two distinct genes, or isolated nucleotide fragments of such genes. In one embodiment of the present invention, a soluble fusion TRANCE protein is disclosed which is a FLAG-tagged

5 soluble form of TRANCE generated by cloning a PCR product encoding the TRANCE ectodomain (amino acid residues 72-316 of SEQ ID NO:4) into the *HindIII-XhoI* sites in the pFLAG/CMV-1 vector (Kodak). In another embodiment, a CD8-TRANCE fusion protein was produced, wherein a the extracellular domain of murine TRANCE (amino acid residues 245-316 of Figure 4 (SEQ ID NO:4)) was

10 fused to human CD8 $\alpha$  (amino acid residues 1-82) and produced in a baculovirus expression system.

The modulator of the present invention also can be an anti-sense TRANCE nucleic acid comprising at least one phosphodiester analog bond. An anti-sense molecule is

15 comprised of RNA or DNA, or analogs or derivatives of RNA or DNA, and has a nucleotide sequence such that it is complementary to a specific RNA transcript of a gene. It is designed to hybridize to the specific RNA to form a duplex and block the function of the specific RNA. The anti-sense molecule of the present invention can prevent the expression of TRANCE in T cells. Hence, no interaction occurs between

20 TRANCE and TRANCE-R on the surface of mature dendritic cells, the signal transduction of TRANCE is blocked, the upregulation of the expression of Bcl-x<sub>L</sub> in the mature dendritic cell is prevented. As a result, apoptosis is not inhibited, and the life span of mature dendritic cells is decreased relative to the life span of mature dendritic cells wherein the TRANCE signal transduction is not blocked.

25 Also included in the modulator of the present invention are antibodies having an immunogen selected from the group consisting of the polypeptide having an amino a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid as set forth in Figure 2 (SEQ ID

30 NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, a

fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof. Such antibodies include but are not limited to polyclonal, monoclonal, chimeric, single chain, Fab fragments, and an Fab expression library.

- 5 The antibodies of the invention may be cross reactive, *e.g.*, they may recognize TRANCE from different species. Polyclonal antibodies have greater likelihood of cross reactivity. Alternatively, an antibody of the invention may be specific for a single form of TRANCE, such as human TRANCE having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), or murine TRANCE, having an amino acid  
10 sequence as set forth in Figure 4 (SEQ ID NO:4).

- Various procedures known in the art may be used for the production of polyclonal antibodies to TRANCE polypeptide or a derivative or analog thereof, or fusion proteins containing TRANCE or a fragment thereof. For the production of an  
15 antibody, various host animals can be immunized by injection with the TRANCE polypeptide, or an analog or derivative (*e.g.*, fragment or fusion protein) thereof, including but not limited to rabbits, mice, rats, sheep, goats, etc. In one embodiment, the TRANCE polypeptide or fragment thereof can be conjugated to an immunogenic carrier, *e.g.*, bovine serum albumin (BSA) or keyhole limpet hemocyanin (KLH).  
20 Various adjuvants may be used to increase the immunological response, depending on the host species, including but not limited to Freund's (complete and incomplete), mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanins, dinitrophenol, and potentially useful human adjuvants such as BCG  
25 (*bacille Calmette-Guerin*) and *Corynebacterium parvum*.

- For preparation of monoclonal antibodies directed toward the TRANCE polypeptide, or fragment, analog or derivative thereof, or fusion protein containing the amino acid residue sequence of TRANCE or a fragment thereof, any technique that provides for  
30 the production of antibody molecules by continuous cell lines in culture may be used. These include but are not limited to the hybridoma technique originally developed by

Kohler and Milstein [*Nature* **256**:495-497 (1975)], as well as the trioma technique, the human B-cell hybridoma technique [Kozbor et al., *Immunology Today* **4**:72 (1983); Cote et al., *Proc. Natl. Acad. Sci. U.S.A.* **80**:2026-2030 (1983)], and the EBV-hybridoma technique to produce human monoclonal antibodies [Cole et al., in  
5 *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, Inc., pp. 77-96 (1985)]. In an additional embodiment of the invention, monoclonal antibodies can be produced in germ-free animals utilizing recent technology [PCT/US90/02545]. In fact, according to the invention, techniques developed for the production of "chimeric antibodies" [Morrison et al., *J. Bacteriol.* **159**:870 (1984); Neuberger et al., *Nature* **312**:604-608  
10 (1984); Takeda et al., *Nature* **314**:452-454 (1985)] by splicing the genes from a mouse antibody molecule specific for a polypeptide together with genes from a human antibody molecule of appropriate biological activity can be used; such antibodies are within the scope of this invention. Such human or humanized chimeric antibodies are preferred for use in therapy of human diseases or disorders (described *infra*), since the  
15 human or humanized antibodies are much less likely than xenogenic antibodies to induce an immune response, in particular an allergic response, themselves.

According to the invention, techniques described for the production of single chain antibodies [U.S. Patent 4,946,778] can be adapted to produce TRANCE polypeptide-  
20 specific single chain antibodies. An additional embodiment of the invention utilizes the techniques described for the construction of Fab expression libraries [Huse et al., *Science* **246**:1275-1281 (1989)] to allow rapid and easy identification of monoclonal Fab fragments with the desired specificity for a TRANCE polypeptide, its derivatives, analogs or fusion proteins.

25 Antibody fragments which contain the idiotype of the antibody molecule can be generated by known techniques. For example, such fragments include but are not limited to: the F(ab')<sub>2</sub> fragment which can be produced by pepsin digestion of the antibody molecule; the Fab' fragments which can be generated by reducing the  
30 disulfide bridges of the F(ab')<sub>2</sub> fragment, and the Fab fragments which can be generated by treating the antibody molecule with papain and a reducing agent.

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In the production of antibodies, screening for the desired antibody can be accomplished by techniques known in the art. *e.g.*, radioimmunoassay, ELISA (enzyme-linked immunosorbant assay), "sandwich" immunoassays,

- immunoradiometric assays, gel diffusion precipitin reactions, immunodiffusion  
 5 assays, *in situ* immunoassays (using colloidal gold, enzyme or radioisotope labels, for example), western blots, precipitation reactions, agglutination assays (*e.g.*, gel agglutination assays, hemagglutination assays), complement fixation assays, immunofluorescence assays, protein A assays, and immunoelectrophoresis assays, etc.
- In one embodiment, antibody binding is detected by detecting a label on the primary  
 10 antibody. In another embodiment, the primary antibody is detected by detecting binding of a secondary antibody or reagent to the primary antibody. In a further embodiment, the secondary antibody is labeled. Many means are known in the art for detecting binding in an immunoassay and are within the scope of the present invention. For example, to select antibodies which recognize a specific epitope of a  
 15 TRANCE polypeptide, one may assay generated hybridomas for a product which binds to a TRANCE polypeptide fragment containing such epitope. For selection of an antibody specific to a TRANCE polypeptide from a particular species of animal, one can select on the basis of positive binding with TRANCE polypeptide expressed by or isolated from T cells of that species of animal. and negative binding with  
 20 TRANCE from other species.

- The foregoing antibodies, particularly if they are detectably labeled, can be used in methods known in the art relating to the localization and activity of the TRANCE polypeptide, *e.g.*, for Western blotting, imaging TRANCE polypeptide *in situ*,  
 25 measuring levels thereof in appropriate physiological samples, etc., using any of the detection techniques mentioned above or known in the art. Moreover, a detectable label for an antibody of the present invention includes, but is not limited to, conjugation of the antibody to an enzyme such as alkaline phosphatase or peroxidase, or the incorporation of radioactive isotopes into the structure of an antibody of the  
 30 present invention.

As explained above, a modulator of the present invention modulates the active life of dendritic cells, and hence effects the immune response and T cell activation in a mammal. It is important to note that the present invention includes modulators that are agonists of TRANCE and *increase* the life span of mature dendritic cells, and

5 modulators that are antagonists of TRANCE and ultimately *decrease* the life span of mature dendritic cells exposed to them relative to the life span of mature dendritic cells not exposed to a such a modulator.

In particular, modulators of the present invention which are agonists of TRANCE and

10 increase the life span of mature dendritic cells, increase T cell activation, and hence increase immune response in a mammal include a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID

15 NO:4), conserved variants thereof, or a fragment thereof, a fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof or a fragment thereof.

Modulators of the present invention that are antagonists of TRANCE prevent the

20 upregulation of expression of Bcl-x<sub>L</sub> in mature dendritic cells so that apoptosis in those cells is not inhibited, resulting in a decrease of the life span of such mature dendritic cells, a decrease T cell activation, and a decrease in immune response to an antigen. One such TRANCE antagonist modulator of the present invention is an anti-sense TRANCE nucleic acid comprising at least one phosphodiester analog bond.

25 Another TRANCE antagonist modulator of the present invention is an antibody having an immunogen a polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants thereof, or a fragment thereof, an analog or derivative of a polypeptide having an amino acid as set forth in Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID NO:4), conserved variants

30 thereof, or a fragment thereof, a fusion protein wherein its amino acid sequence contains the amino acid sequence of Figure 2 (SEQ ID NO:2), Figure 4 (SEQ ID

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NO:4), conserved variants thereof or a fragment thereof.

### Pharmaceutical Compositions

Also provided in the present invention are pharmaceutical compositions comprising  
5 modulators of the present invention, and a pharmaceutically acceptable carrier  
thereof. The phrase "pharmaceutically acceptable" refers to molecular entities and  
compositions that are physiologically tolerable and do not typically produce an  
allergic or similar untoward reaction, such as gastric upset, dizziness and the like,  
when administered to a human.

10

Such pharmaceutical compositions may be for administration for injection, or for  
oral, pulmonary, nasal or other forms of administration. In general, comprehended  
by the invention are pharmaceutical compositions comprising effective amounts of a  
low molecular weight component or components, or derivative products, of the  
15 invention together with pharmaceutically acceptable diluents, preservatives,  
solubilizers, emulsifiers, adjuvants and/or carriers. Such compositions include  
diluents of various buffer content (*e.g.*, Tris-HCl, acetate, phosphate), pH and ionic  
strength; additives such as detergents and solubilizing agents (*e.g.*, Tween 80,  
Polysorbate 80), anti-oxidants (*e.g.*, ascorbic acid, sodium metabisulfite),  
20 preservatives (*e.g.*, Thimersol, benzyl alcohol) and bulking substances (*e.g.*,  
lactose, mannitol); incorporation of the material into particulate preparations of  
polymeric compounds such as polylactic acid, polyglycolic acid, etc. or into  
liposomes. Hylauronic acid may also be used. Such compositions may influence the  
physical state, stability, rate of *in vivo* release, and rate of *in vivo* clearance of the  
25 present proteins and derivatives. *See, e.g.*, Remington's Pharmaceutical Sciences,  
18th Ed. (1990, Mack Publishing Co., Easton, PA 18042) pages 1435-1712 which  
are herein incorporated by reference. The compositions may be prepared in liquid  
form, or may be in dried powder, such as lyophilized form.

30

### Oral Delivery

Contemplated for use herein are oral solid dosage forms, which are described

generally in Remington's Pharmaceutical Sciences, 18th Ed. 1990 (Mack Publishing Co. Easton PA 18042) at Chapter 89, which is herein incorporated by reference. Solid dosage forms include tablets, capsules, pills, troches or lozenges, cachets or pellets. Also, liposomal or proteinoid encapsulation may be used to formulate the

5 present compositions (as, for example, proteinoid microspheres reported in U.S. Patent No. 4,925,673). Liposomal encapsulation may be used and the liposomes may be derivatized with various polymers (*e.g.*, U.S. Patent No. 5,013,556). A description of possible solid dosage forms for the therapeutic is given by Marshall, K. In: *Modern Pharmaceutics* Edited by G.S. Banker and C.T. Rhodes Chapter 10,

10 1979, herein incorporated by reference. In general, the formulation will include the the modulator of the present invention and inert ingredients which allow for protection against the stomach environment, and release of the biologically active material in the intestine.

15 Also specifically contemplated are oral dosage forms of the the modulator. The modulator may be chemically modified so that oral delivery of the the analog or derivative of TRANCE is efficacious. Generally, the chemical modification contemplated is the attachment of at least one moiety to the modulator, where said moiety permits (a) inhibition of proteolysis; and (b) uptake into the blood stream

20 from the stomach or intestine. Also desired is the increase in overall stability of the the modulator and increase in circulation time in the body. Examples of such moieties include: polyethylene glycol, copolymers of ethylene glycol and propylene glycol, carboxymethyl cellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone and polyproline. Abuchowski and Davis, 1981, "Soluble Polymer-Enzyme

25 Adducts" In: *Enzymes as Drugs*, Hocenberg and Roberts, eds., Wiley-Interscience, New York, NY, pp. 367-383; Newmark, et al., 1982, *J. Appl. Biochem.* 4:185-189. Other polymers that could be used are poly-1,3-dioxolane and poly-1,3,6-tioxocane. Preferred for pharmaceutical usage, as indicated above, are polyethylene glycol moieties.

30 For the modulator, the location of release may be the stomach, the small intestine (the

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duodenum, the jejunum, or the ileum), or the large intestine. One skilled in the art has available formulations which will not dissolve in the stomach, yet will release the material in the duodenum or elsewhere in the intestine. Preferably, the release will avoid the deleterious effects of the stomach environment, either by protection of the modulator or by release of the the modulator in the pharmaceutical composition beyond the stomach environment, such as in the intestine.

To ensure full gastric resistance a coating impermeable to at least pH 5.0 is essential. Examples of the more common inert ingredients that are used as enteric coatings are cellulose acetate trimellitate (CAT), hydroxypropylmethylcellulose phthalate (HPMCP), HPMCP 50, HPMCP 55, polyvinyl acetate phthalate (PVAP), Eudragit L30D, Aquateric, cellulose acetate phthalate (CAP), Eudragit L, Eudragit S, and Shellac. These coatings may be used as mixed films.

A coating or mixture of coatings can also be used on tablets, which are not intended for protection against the stomach. This can include sugar coatings, or coatings which make the tablet easier to swallow. Capsules may consist of a hard shell (such as gelatin) for delivery of dry therapeutic i.e. powder; for liquid forms, a soft gelatin shell may be used. The shell material of cachets could be thick starch or other edible paper. For pills, lozenges, molded tablets or tablet triturates, moist massing techniques can be used.

The pharmaceutical composition can be included in the formulation as fine multi-particulates in the form of granules or pellets of particle size about 1 mm. The formulation of the pharmaceutical composition for capsule administration could also be as a powder, lightly compressed plugs or even as tablets. The pharmaceutical composition could be prepared by compression.

Colorants and flavoring agents may all be included. For example, modulator may be formulated (such as by liposome or microsphere encapsulation) and then further contained within an edible product, such as a refrigerated beverage containing



colorants and flavoring agents.

One may dilute or increase the volume of the pharmaceutical composition with an inert material. These diluents could include carbohydrates, especially mannitol,  
 5 a-lactose, anhydrous lactose, cellulose, sucrose, modified dextrans and starch. Certain inorganic salts may be also be used as fillers including calcium triphosphate, magnesium carbonate and sodium chloride. Some commercially available diluents are Fast-Flo, Emdex, STA-Rx 1500, Emcompress and Avicell.

10 Disintegrants may be included in the formulation of the pharmaceutical composition into a solid dosage form. Materials used as disintegrates include but are not limited to starch, including the commercial disintegrant based on starch, "EXPLOTAB."  
 Sodium starch glycolate, Amberlite, sodium carboxymethylcellulose, ultramylopectin, sodium alginate, gelatin, orange peel, acid carboxymethyl cellulose, natural sponge  
 15 and bentonite may all be used. Another form of the disintegrants are the insoluble cationic exchange resins. Powdered gums may be used as disintegrants and as binders and these can include powdered gums such as agar, Karaya or tragacanth. Alginic acid and its sodium salt are also useful as disintegrants.

20 Binders may be used to hold the pharmaceutical composition together to form a hard tablet and include materials from natural products such as acacia, tragacanth, starch and gelatin. Others include methyl cellulose (MC), ethyl cellulose (EC) and carboxymethyl cellulose (CMC). Polyvinyl pyrrolidone (PVP) and hydroxypropylmethyl cellulose (HPMC) could both be used in alcoholic solutions to  
 25 granulate the therapeutic.

An anti-frictional agent may be included in the formulation of the pharmaceutical composition to prevent sticking during the formulation process. Lubricants may be used as a layer between the pharmaceutical composition and the die wall, and these  
 30 can include but are not limited to; stearic acid including its magnesium and calcium salts, polytetrafluoroethylene (PTFE), liquid paraffin, vegetable oils and waxes.

Soluble lubricants may also be used such as sodium lauryl sulfate, magnesium lauryl sulfate, polyethylene glycol of various molecular weights, Carbowax 4000 and 6000.

Glidants that might improve the flow properties of the pharmaceutical composition during formulation and to aid rearrangement during compression might be added. The glidants may include starch, talc, pyrogenic silica and hydrated silicoaluminate.

To aid dissolution of the pharmaceutical composition into the aqueous environment a surfactant might be added as a wetting agent. Surfactants may include anionic detergents such as sodium lauryl sulfate, dioctyl sodium sulfosuccinate and dioctyl sodium sulfonate. Cationic detergents might be used and could include benzalkonium chloride or benzethonium chloride. The list of potential non-ionic detergents that could be included in the formulation as surfactants are lauromacrogol 400, polyoxyl 40 stearate, polyoxyethylene hydrogenated castor oil 10, 50 and 60, glycerol monostearate, polysorbate 40, 60, 65 and 80, sucrose fatty acid ester, methyl cellulose and carboxymethyl cellulose. These surfactants could be present in the formulation of the modulator either alone or as a mixture in different ratios.

Additives which potentially enhance uptake of the modulator are for instance the fatty acids oleic acid, linoleic acid and linolenic acid.

Controlled release oral formulation may be desirable. The pharmaceutical composition could be incorporated into an inert matrix which permits release by either diffusion or leaching mechanisms, *e.g.*, gums. Slowly degenerating matrices may also be incorporated into the formulation. Some enteric coatings also have a delayed release effect.

Another form of a controlled release of the pharmaceutical composition of the present invention is by a method based on the "OROS" therapeutic system (Alza Corp.), *i.e.* the pharmaceutical composition is enclosed in a semipermeable membrane which allows water to enter and push drug out through a single small opening due to osmotic

effects.

Other coatings may be used for the formulation. These include a variety of sugars which could be applied in a coating pan. The therapeutic agent could also be given in a film coated tablet and the materials used in this instance are divided into 2 groups. The first are the nonenteric materials and include methyl cellulose, ethyl cellulose, hydroxyethyl cellulose, methylhydroxy-ethyl cellulose, hydroxypropyl cellulose, hydroxypropyl-methyl cellulose, sodium carboxy-methyl cellulose, providone and the polyethylene glycols. The second group consists of the enteric materials that are commonly esters of phthalic acid.

A mix of materials might be used to provide the optimum film coating. Film coating may be carried out in a pan-coater or in a fluidized bed or by compression coating.

*Pulmonary Delivery.* Also contemplated herein is pulmonary delivery of the modulators of the present invention. The pharmaceutical composition is delivered to the lungs of a mammal while inhaling and traverses across the lung epithelial lining to the blood stream. Other reports of this include Adjei et al., 1990, *Pharmaceutical Research*, 7:565-569; Adjei et al., 1990, *International Journal of Pharmaceutics*, 63:135-144 (leuprolide acetate); Braquet et al., 1989, *Journal of Cardiovascular Pharmacology*, 13(suppl. 5):143-146 (endothelin-1); Hubbard et al., 1989, *Annals of Internal Medicine*, Vol. III, pp. 206-212 (a1- antitrypsin); Smith et al., 1989, *J. Clin. Invest.* 84:1145-1146 (a-1-proteinase); Oswein et al., 1990, "Aerosolization of Proteins", *Proceedings of Symposium on Respiratory Drug Delivery II*. Keystone, Colorado, March. (recombinant human growth hormone); Debs et al., 1988, *J. Immunol.* 140:3482-3488 (interferon-g and tumor necrosis factor alpha) and Platz et al., U.S. Patent No. 5,284,656 (granulocyte colony stimulating factor). A method and composition for pulmonary delivery of drugs for systemic effect is described in U.S. Patent No. 5,451,569, issued September 19, 1995 to Wong et al.

30

Contemplated for use in the practice of this invention are a wide range of mechanical

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devices designed for pulmonary delivery of therapeutic products, including but not limited to nebulizers, metered dose inhalers, and powder inhalers, all of which are familiar to those skilled in the art.

- 5 Some specific examples of commercially available devices suitable for the practice of this invention are the "ULTRAVENT" nebulizer, manufactured by Mallinckrodt, Inc., St. Louis, Missouri; the "ACORN II" nebulizer, manufactured by Marquest Medical Products, Englewood, Colorado; the "VENTOLIN" metered dose inhaler, manufactured by Glaxo Inc., Research Triangle Park, North Carolina; and the
- 10 "SPINHALER" powder inhaler, manufactured by Fisons Corp., Bedford, Massachusetts.

- All such devices require the use of formulations suitable for the dispensing of the modulator. Typically, each formulation is specific to the type of device employed and
- 15 may involve the use of an appropriate propellant material, in addition to the usual diluents, adjuvants and/or carriers useful in therapy. Also, the use of liposomes, microcapsules or microspheres, inclusion complexes, or other types of carriers is contemplated. Chemically modified modulator may also be prepared in different formulations depending on the type of chemical modification or the type of device
- 20 employed.

- Formulations suitable for use with a nebulizer, either jet or ultrasonic, will typically comprise the modulator of the present invention dissolved in water at a concentration of about 0.1 to 25 mg of biologically active molecule per mL of solution. The
- 25 formulation may also include a buffer and a simple sugar (*e.g.*, for protein stabilization and regulation of osmotic pressure). The nebulizer formulation may also contain a surfactant, to reduce or prevent surface induced aggregation of the modulator caused by atomization of the solution in forming the aerosol.
- 30 Formulations for use with a metered-dose inhaler device will generally comprise a finely divided powder containing the modulator suspended in a propellant with the aid

of a surfactant. The propellant may be any conventional material employed for this purpose, such as a chlorofluorocarbon, a hydrochlorofluorocarbon, a hydrofluorocarbon, or a hydrocarbon, including trichlorofluoromethane, dichlorodifluoromethane, dichlorotetrafluoroethanol, and 1,1,1,2-tetrafluoroethane, or combinations thereof. Suitable surfactants include sorbitan trioleate and soya lecithin. Oleic acid may also be useful as a surfactant.

Formulations for dispensing from a powder inhaler device will comprise a finely divided dry powder containing the modulator and may also include a bulking agent, such as lactose, sorbitol, sucrose, or mannitol in amounts which facilitate dispersal of the powder from the device, *e.g.*, 50 to 90% by weight of the formulation. The modulator should most advantageously be prepared in particulate form with an average particle size of less than 10  $\mu$ m (or microns), most preferably 0.5 to 5  $\mu$ m, for most effective delivery to the distal lung.

*Nasal Delivery.* Nasal delivery of the pharmaceutical composition of the present invention is also contemplated. Nasal delivery allows the passage of the modulator to the blood stream directly after administering the pharmaceutical composition to the nose, without the necessity for deposition of the product in the lung. Formulations for nasal delivery include those with dextran or cyclodextran.

As explained above, the present invention discloses a TRANCE agonist pharmaceutical comprising a modulator which is an agonist of TRANCE and selected from the group consisting of the polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or a fragment thereof, the polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4) or a fragment thereof, the analog or derivative the polypeptide having an amino acid as set forth in Figure 4 (SEQ ID NO:4) or a fragment thereof, the fusion protein containing the amino acid sequence of Figure 2 (SEQ ID NO:2) or a fragment thereof, and the fusion protein containing the amino acid sequence of Figure 4 (SEQ ID NO:4) or a fragment thereof, along with a pharmaceutically acceptable carrier thereof.

Moreover, the present invention discloses a TRANCE antagonist pharmaceutical composition comprising an antagonist of TRANCE, selected from the group consisting of the anti-sense TRANCE nucleic acid comprising at least one phosphodiester analog bond, and the antibody having an immunogen selected from the group consisting of the

5 polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or a fragment thereof, the polypeptide having an amino acid sequence as set forth in Figure 4 (SEQ ID NO:4) or a fragment thereof, the analog or derivative of the polypeptide having an amino acid sequence as set forth in Figure 2 (SEQ ID NO:2) or a fragment thereof, the analog or derivative of the polypeptide having an amino acid

10 sequence as set forth in Figure 4 (SEQ ID NO:4) or a fragment thereof, the fusion protein containing the amino acid sequence of Figure 2 (SEQ ID NO:2), or a fragment thereof, and the fusion protein containing the amino acid sequence of Figure 4 (SEQ ID NO:4), or a fragment thereof, and a pharmaceutically acceptable carrier thereof.

#### 15 Methods for Treating Immune System Related Conditions With the Present Invention

Pharmaceutical compositions of the present invention discussed above can be used to treat immune system related conditions in a mammal. In particular, included in the present invention is a method to treat an immune system related condition in a

20 mammal with a TRANCE agonist pharmaceutical composition, comprising the steps of exposing at least one mature dendritic cell of the mammal to an antigen so that the at least one mature dendritic cell can present the antigen on its surface, and administering to the mammal a therapeutically effective amount of the TRANCE agonist pharmaceutical composition. In this method, the antigen can include, but is

25 not limited to, a pathogen or a fragment thereof, a virus or a fragment thereof, or a tumor, or a fragment thereof. Moreover, the immune system related condition which can be treated with the present invention includes, but is not limited to viruses, such as HIV or cancer.

30 As explained above, two costimulatory signals are necessary to activate T cells against a particular antigen presented on the surface of a mature dendritic cell. One

signal is from the antigen bound to an MHC molecule on the surface of the mature dendritic cell. This complex interacts with the T cell receptor complex on the surface of the T cell. The other signal results from molecules produced by the mature dendritic cell that bind to receptors on the T cell. The T cell becomes activated upon receiving both signals, and undergoes an autocrine process wherein it separates from the dendritic cell and simultaneously secretes a growth factor like IL-2 along with cell-surface receptors that bind to it. The binding of IL-2 to its receptor stimulates the T cell to proliferate, so long as it has already encountered its specific antigen. After receiving these signals, the activated T cell departs and the antigen presenting mature dendritic cell is available to activate another T cell. Hence, TRANCE agonist modulators of the present invention mimic TRANCE, and induce upregulation of expression of Bcl-x<sub>L</sub> in mature dendritic cells, which inhibits apoptosis. As a result, the life span of the mature dendritic cell exposed to the TRANCE agonist modulator is increased relative to the life span of mature dendritic cells which are not exposed to the TRANCE agonist modulator. This life span increase permits the mature dendritic cells presenting antigens to activate a greater number of T cells than mature dendritic cells not exposed to TRANCE or the TRANCE agonist modulator. Hence, the immune response of the mammal is ultimately increased, since T cell activation contributes to the response. Consequently, this method of the present invention modulates T cell activation in the mammal and permits the treatment of an immune system related condition. The antigen may be a pathagen, or a fragment thereof, a virus, or a fragment thereof, or an antigen from a tumor.

The exposure of the mature dendritic cell to the antigen can occur *in vivo* or *in vitro*. If it occurs *in vivo*, the antigen is administered to the mammal so that mature dendritic cells of the mammal can interact with the antigen and present it on their surfaces. If the exposure occurs *ex vivo*, then at least one mature dendritic cell is removed from the mammal, exposed to the antigen *ex vivo* so that the antigen can be presented on its surface, and then reintroduced into the mammal prior to administering the TRANCE agonist pharmaceutical composition.

Moreover, the TRANCE antagonist pharmaceutical composition can also be used in a method to treat immune system related conditions. In particular, disclosed herein is a method for treating an immune system related condition in a mammal comprising administering to the mammal a therapeutically effective amount of a TRANCE

5 antagonist pharmaceutical composition. In this embodiment, the immune system related condition is related to over-expression of TRANCE in the mammal. Autoimmune disease is an example of an immune system related condition involving overexpression of a protein receptor of the TNF superfamily. Hence, since TRANCE is a member of the TNF superfamily, its over expression can also result in an immune

10 system related condition. As a result, this method can be used to treat such a condition. Moreover, this method can be used to to treat hypersensitivity in a mammal towards an allergen. Since the TRANCE antagonist pharmaceutical composition decreases immune response, this method can be used to induce anergy in a mammal and decrease the mammal's immune response towards an allergen.

15 The phrase "therapeutically effective amount" is used herein to mean an amount sufficient to prevent, and preferably reduce by at least about 30 percent, more preferably by at least 50 percent, most preferably by at least 90 percent, a clinically significant change in the S phase activity of a host cellular mass, or other feature of

20 pathology such as for example, elevated blood pressure, fever or white cell count as may attend its presence and activity.

*Dosages.* For all of the above pharmaceutical compositions, as further studies are conducted, information will emerge regarding appropriate dosage levels for treatment

25 of various conditions in various patients, and the ordinary skilled worker, considering the therapeutic context, age and general health of the recipient, will be able to ascertain proper dosing.

#### Gene Therapy

30 Also disclosed herein is a method for modifying levels of expression of a TRANCE protein in a mammal, comprising the steps of removing at least one hematopoietic



stem cell from the mammal, destroying remaining hematopoietic stem cells in the mammal, transfecting the at least one hematopoietic stem cell with a vector containing a nucleic acid molecule which encodes a TRANCE protein such that the nucleic acid molecule becomes incorporated into the genome of the hematopoietic stem cell,

5 forming a transfected hematopoietic stem cell, and introducing the transfected hematopoietic stem into the mammal so that the transfected hematopoietic stem cell can self replicate and differentiate within the mammal. Such a method can be used to treat a mammal in which TRANCE is not expressed.

10 The method for removing of a stem cell from a mammal is well known in the art. Moreover, transfecting such a cell with an expression vector of the present invention such that a gene expressing TRANCE operatively associated with a promoter is incorporated into the genome of the stem cell is also included in the present invention.

15 Destruction of remaining stem cells in the mammal can be done with numerous protocols, such as for example, radiation treatments. It is important however, that the mammal be kept in a germ free environment as its immune system will be unable to protect it from foreign viruses, bacteria and pathogens.

20 After all remaining stem cells of the mammal have been destroyed, the transfected stem cell can be reintroduced into the mammal, wherein it replicates and differentiates. As a result, the immune system is repopulated with T cells that can express TRANCE.

25 In one embodiment of the present invention, this method is used to modify TRANCE expression in a human, and the expression vector used to transfect the stem cell contains the isolated nucleic acid sequence of Figure 1 (SEQ ID NO:1) operatively associated with a promoter.

30

#### Diagnostics

The antibodies or isolated nucleic acids of the invention can be used in diagnosis of

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diseases or disorders associated with apparent defects in TRANCE activity by evaluating the level of expression of a functional TRANCE in a bodily sample. In particular, nucleic acid probes or PCR primers can be used to verify expression of mRNA coding for TRANCE in standard protocols, such as Northern blots, Southern blots, and RT-PCR followed by a Southern blot. Moreover, anti-TRANCE antibodies of the present invention can be used in numerous immunoassays known in the art to detect the expression of TRANCE in a bodily sample. In particular, the antibodies of the present invention can be used to detect expression of TRANCE in cells, and in some instances, to localize its expression on the surface of T cells.

10

In specific embodiments, a deficiency in TRANCE activity may be evaluated in the context of a disease or disorder associated with a deficiency of a TNF protein. For example, a deficiency of the TNF receptor family protein CD40 results in an immune system related condition called Hyper IGM syndrome. In another example Autoimmune Human Lymphoproliferative Syndrome (ALPS) is a condition caused by a mutation in the TNF receptor family protein Fas, such that the protein is not expressed, or is expressed in a mutated form with either no activity or decreased activity relative to the wildtype Fas protein. Consequently, a deficiency of TRANCE expression in an appropriate bodily sample of a mammal is indicative of the presence of an immune system related condition in the mammal. Appropriate bodily samples include, but are not limited to, blood and lymphoid tissue such as lymph node tissue, spleen tissue, or thymus tissue.

Screening a bodily sample as described above for expression of TRANCE can be accomplished with the antibodies of the present invention (including antibodies which are TRANCE antagonist modulators ) by techniques known in the art, *e.g.*, radioimmunoassay, ELISA (enzyme-linked immunosorbant assay), "sandwich" immunoassays, immunoradiometric assays, gel diffusion precipitin reactions, immunodiffusion assays, *in situ* immunoassays (using colloidal gold, enzyme or radioisotope labels, for example), western blots, precipitation reactions, agglutination assays (*e.g.*, gel agglutination assays, hemagglutination assays), complement fixation

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assays, immunofluorescence assays, protein A assays, and immunoelectrophoresis assays, etc. In one embodiment, TRANCE antibody binding to TRANCE or a fragment thereof is detected by detecting a label conjugated to the TRANCE antibody. In another embodiment, the TRANCE antibody is detected by detecting binding of a secondary antibody or reagent to the primary antibody. In a further embodiment, the secondary antibody is labeled. Many means are known in the art for detecting binding in an immunoassay and are within the scope of the present invention.

Moreover, the isolated nucleic acid sequences of the present invention can be used to screen for the expression of TRANCE in a bodily sample. For example, The mRNA from a bodily sample can be isolated, and immobilized on a solid support, such as nitrocellulose or polyvinylidene difluoride (PVDF). This support can then be incubated with the isolated nucleic acid molecule of Figure 1 (SEQ ID 1) or a fragment thereof conjugated to a label to form a "probe". Numerous methods of labeling DNA are known in the art, including, but not limited to the incorporation of radioactive isotopes into the DNA. This probe is complementary to TRANCE mRNA in a sample and will form a duplex with it. Hence, the detection of this duplex on the solid support indicates that the TRANCE gene in the sample is being transcribed into mRNA, which, in turn, should be translated into a protein. However, if no such duplex is detected, it is probable that the TRANCE is not being expressed, and hence the mammal lacks functional TRANCE.

The present invention may be better understood by reference to the following non-limiting Examples, which are provided as exemplary of the invention.

### EXAMPLES

EXAMPLE 1: TRANCE Is a Novel Ligand of the Tumor Necrosis Factor Receptor Family That Activates c-Jun N-terminal Kinase in T cells

A novel member of the tumor necrosis factor (TNF) cytokine family, designated TRANCE, was cloned during a search for apoptosis-regulatory genes using a somatic cell genetic approach in T cell hybridomas. The TRANCE gene encodes a type II  
 5 membrane protein of 316 amino acids with a predicted molecular weight of 35 kD. Its extracellular domain is most closely related to TRAIL, FasL and TNF. TRANCE is an immediate early gene upregulated by TCR stimulation and is controlled by calcineurin-regulated transcription factors. TRANCE is most highly expressed in thymus and lymph nodes but not in non-lymphoid tissues and is abundantly expressed  
 10 in T cells but not in B cells. Cross-hybridization of the mouse cDNA to a human thymus library yielded the human homolog, which encodes a protein 83% identical to the mouse ectodomain. Human *TRANCE* was mapped to chromosome 13q14 while mouse *TRANCE* was located to the portion of mouse chromosome 14 syntenic with human chromosome 13q14. A recombinant soluble form of TRANCE composed of  
 15 the entire ectodomain induced c-Jun N-terminal kinase (JNK) activation in T cells but not in splenic B cells or in bone-marrow-derived dendritic cells. These results suggest a role for this TNF-related ligand in the regulation of the T cell dependent immune response.

20 The TNF cytokine family currently includes TNF, LT- $\alpha$ , LT- $\beta$ , FasL, CD40L, CD30L, CD27L, 4-1BBL, OX40L (1) and TRAIL/APO-2L (2, 3) which exhibit the highest homology between their C-terminal, receptor binding domains. The family members are type II membrane proteins that act in an autocrine, paracrine or endocrine manner either as integral membrane proteins or as proteolytically processed  
 25 soluble effectors. Binding to their cognate receptors leads to the activation of several signal transduction pathways: the cascade of caspase/ICE-like proteases, the nuclear factor- $\kappa$ B (NF- $\kappa$ B) family of transcription factors and the mitogen-activated protein kinases including the c-Jun N-terminal protein kinases (JNK), and the extracellularly-regulated kinases (ERK) (4-6).

30

The biochemical pathways activated by the TNF-related ligands are coordinated to

effect a diverse set of biological responses including apoptosis, differentiation, proliferation, and survival (1). Caspases execute the biochemical events leading to apoptosis (4) whereas NF- $\kappa$ B appears to inhibit cell death (7). In addition to its anti-apoptotic role, NF- $\kappa$ B regulates numerous genes, such as cytokines and adhesion molecules, that are critical in triggering and maintaining immune-mediated inflammatory responses (8). TNFR1, TNFR2, CD30, CD40, DR3/wsl-1/TRAMP/Apo-3, and the TRAIL receptor, when stimulated or over expressed, recruit TRAF2, a signal transducing protein that activates JNK *in vitro* (9). Fas can activate JNK by recruiting the protein Daxx to its death domain (10). Thus, JNK activation appears to be a common signaling event downstream of TNF-related ligand/receptor binding. JNK is linked to lymphocyte activation and proliferation since it can activate c-Jun, a component of the nuclear factor of activated T cells (NFAT) and activator protein-1 (AP-1) (11). Emerging evidence suggests that JNK is also critical in mediating apoptosis in non-lymphoid cells in response to some (10, 12-14), but not all physiologic agonists, e.g., TNFR1 mediated cell death (9, 15).

The expression of TNF-related ligands on T cells are regulated by signaling from the T cell receptor (TCR) and mediate many of its biological effects. FasL, TNF and CD30L are responsible for TCR-mediated apoptosis of T cells and immature thymocytes (16, 17). Seven of the TNF family members, in conjunction with TCR-stimulation, can enhance T cell proliferation (1). Therefore, upregulation of TNF cytokine members and their receptors by the TCR may provide an autocrine costimulatory mechanism to enhance the cells' own proliferation after stimulation with antigen (1). The TCR also upregulates TNF-related ligands for the purposes of B cell co-stimulation, protection against Ig antigen-receptor induced apoptosis and antibody isotype switching (18-20), dendritic cell activation and differentiation (21), and of inducing apoptosis in virally infected cells or transformed cells (22).

To investigate the molecular regulation of TCR-mediated apoptosis a cloning strategy based on somatic cell genetics (23) was used, in which gene expression in mutant T cell hybridomas, resistant to TCR-mediated cell death yet capable of other receptor-associated functions (e.g. IL-2 secretion), is compared with gene expression in wild-

type cells sensitive to TCR-mediated cell death. Such a strategy should yield genes associated with apoptosis and not activation although it is possible to obtain genes involved in other processes. This technique was used successfully to clone the gene TDAG51, a gene required for Fas expression and TCR-mediated cell death (24).

- 5 Using similar methods new member of the TNF cytokine family, designated TRANCE (TNF-related activation-induced cytokine) was cloned, which is predominantly expressed on T cells and in lymphoid organs and is controlled by the TCR through a calcineurin-regulated pathway. A soluble form of the ligand consisting only of the extracellular domain can activate c-Jun N-terminal kinase
- 10 (JNK) specifically in T cells but not in B cells or bone-marrow derived dendritic cells. These results suggest that TRANCE plays a specific role in regulating T cell functions.

#### Materials and Methods

- 15 *Subtractive hybridization and differential screening.*  $1 \times 10^8$  KMI8.3.5.1 or KIT50.1.9.1 T cell hybridomas, were incubated on 15 cm plates coated with 5  $\mu$ g/mL of H57-597 ( $\alpha$ -TCR Ab) as previously described (24). Poly A(+) RNA was extracted using a FastTrack 2.0 mRNA isolation kit (Invitrogen) and 2  $\mu$ g from TCR-stimulated KMI8.3.5.1 (KMI8.3.5.1+) and TCR-stimulated KIT50.1.9.1 (KIT50.1.9.1+) was
- 20 used to make tester and driver cDNA, respectively. Suppression subtractive hybridization was performed using the PCR-select cDNA subtraction kit according to the manufacturer's protocol (Clontech). Briefly, tester and driver was digested with *RsaI* and the tester was ligated to adapter DNA. After two hybridizations with the tester and driver cDNA (20 h and 8 h) the resulting mixture was diluted 1:1000 and
- 25 amplified by PCR using flanking and nested primers to produce a subtracted and normalized PCR fragment library. The efficiency of subtraction was verified via Southern blot analysis of the unsubtracted and subtracted PCR products using a  $^{32}$ P-labeled GAPDH cDNA probe. 26 primary cycles and 18 secondary cycles of PCR amplification yielded the greatest signal:noise ratio estimated by comparing the
- 30 amount of PCR product synthesized to the amount of GAPDH in the subtracted product (data not shown). Using these conditions, subtracted PCR products were TA

cloned into the pCR2.1 plasmid (Invitrogen). To screen differentially expressed products 100 ng of plasmid DNA containing the subtracted fragments were immobilized on duplicate nitrocellulose filters using a slot blot apparatus (Schleicher and Schuell) and hybridized to cDNA probes ( $1 \times 10^7$  cpm/mL) derived from either  
 5 KIT50.1.9.1+ or KMLs8.3.5.1+ poly A(+) RNA. Signals were quantified using a phosphorimager (Molecular Dynamics).

*Full length cloning of murine and human TRANCE cDNA.* A subtracted cDNA fragment, designated 8-50.51, which scored positive in the differential screening assay  
 10 was used to screen a  $\lambda$ ZAP cDNA library derived from KMLs8.3.5.1+ (24). The longest clone (2.2 kb) was sequenced with a Sequenase 2.0 kit (United States Biochemical) over both sense and anti-sense directions using a series of oligonucleotide primers. To clone the human homolog a *Bam*HI-*Bam*HI fragment corresponding to TRANCE (nt 366-1035) was used to screen  $1 \times 10^6$  phage from a  
 15  $\lambda$ gt11 5'-Stretch Plus human leukemia library (Clontech) using low stringency hybridization conditions. A partial human clone was sequenced using the same method described for murine TRANCE.

*Mouse cell purification.* All cells were harvested from 4-8 week old BALB/c mice  
 20 (The Jackson Laboratory). T cell enrichment: T cells were purified from  $5 \times 10^7$  lymph node cells using a T cell enrichment kit (Biotex). B cell enrichment:  $5 \times 10^7$  splenocytes were negatively selected for T cells via magnetic beads conjugated to anti-mouse Thy 1.2 following the manufacturer's protocol (Dynabeads Thy 1.2, Dynal). Bone-marrow derived-dendritic cell enrichment (BMDC): Mature BMDC  
 25 were isolated as previously described (25). Proliferating and apoptotic lymph node T cells (LNTC): LNTC were harvested and treated with concanavalin A (ConA; 5  $\mu$ g/mL) plus IL-2 (10 U/mL) for 48 h and then with IL-2 alone (50 U/mL) for 48 h to yield proliferating T cells (17). To induce cell death, the proliferating T cells were incubated on  $\alpha$ -CD3 $\epsilon$  (145-2C11) coated plates for 6-72 hours as previously  
 30 described (17). Using these conditions, ~ 50% of the cells are dead by 48 h versus ~ 5% cell death in the cells treated with ConA plus IL-2 alone. The purity of T, B and

BMDC enriched fractions was tested by FACS and in all cases was greater than 90%.

*Northern Analysis and Semi-Quantitative PCR.* Expression and regulation of

TRANCE in T cell hybridomas was determined by Northern blot analysis of poly

- 5 A(+) RNA extracted at the indicated time points from the following samples:  
unstimulated or TCR-stimulated cells either in the presence of media alone, FK506  
(10 ng/mL; Fujisawa USA) or cycloheximide (1 µg/mL; Sigma). The 8-50.51  
fragment was used as a probe. To determine TRANCE expression in mouse tissues or  
in stimulated LNTC, total RNA was extracted from various organs or cells as  
10 previously described (24) and 20 µg from each sample was analyzed by Northern blot  
using the TRANCE full length cDNA as a probe. A 28S ribosomal RNA probe (data  
not shown) or a GAPDH cDNA probe was used to control for RNA loading. For  
semi-quantitative PCR analysis total RNA was extracted from T or B cell enriched  
fractions using the RNA Isolation Kit (Stratagene) and first strand cDNA was  
15 transcribed from 1 µg of RNA using Superscript RT (Gibco BRL) following the  
protocol provided by the supplier. The first strand reaction was diluted 1:100,  
allowing amplification to occur as linear function of starting concentrations, and was  
subjected to PCR using the following conditions: β-Actin: (sense: 5'-ATG AAG ATC  
C.G. ACC GAG CG-3' (SEQ ID NO:9), antisense: 5'-TAC TTG CGC TGA GGA  
20 GGA GC-3' (SEQ ID NO:10), 94°C 30 sec, 50°C 1 min, 72°C 1 min for 30 cycles).  
TRANCE: sense: 5'-CCT GAG ACT CCA TGA AAA CGC-3' (SEQ ID NO:11),  
antisense: 5'-TAA CCC TTA GTT TTC CGT TGC-3' (SEQ ID NO:12), 94°C 30 sec,  
52°C 1 min, 72°C 1 min for 30 cycles). The PCR products were analyzed by  
Southern blot as previously described (24).

25

*Expression and Purification of Soluble TRANCE.* A FLAG-tagged soluble form of  
TRANCE was generated by cloning a PCR product encoding the TRANCE  
ectodomain (amino acid residues 72-316 of Figure 2 (SEQ ID NO:2)) into the *HindIII*  
- *XhoI* sites in the pFLAG/CMV-1 vector (Kodak). The open reading frame and  
30 FLAG fusion was confirmed by sequencing. 293T cells were transfected with the  
expression construct (20 µg/10 cm plate) by the calcium phosphate method.



Supernatant was harvested 72 h later, passed through a 0.45  $\mu$ m filter, incubated with the  $\alpha$ -FLAG M2 affinity gel (Kodak) and eluted with the FLAG peptide (250  $\mu$ g/mL; Kodak) as outlined in the manufacturer's protocol. The eluant was dialyzed against PBS, adjusted to 10% glycerol and the protein concentration was ascertained in a

5 BCA protein assay (Pierce).

*Chromosomal localization of murine and human TRANCE. Human TRANCE*

mapping: A Genebridge 4 radiation hybrid mapping panel was obtained from Research Genetics, Inc. (Huntsville, AL). Hybrid DNA was subjected to PCR (94°C 20 sec, 55 °C 15 sec, 72°C 1 min, for 30 cycles) with primers derived from the 3'-

- 10 UTR of the human TRANCE mRNA. Analysis of the data was performed using the radiation hybrid mapping server at the Whitehead Institute/MIT Center for Genome Research as previously described (26). Murine TRANCE mapping: Murine TRANCE was mapped using an intersubspecific backcross. A TRANCE specific genomic DNA fragment of 582 bp was amplified by PCR using synthetic
- 15 oligonucleotide primers (5'-ACC CAG ATG GAC TTC TGT GG-3' (SEQ ID NO:13), 5'-TTT CCT TCG ACG TGC TAX CG-3' (SEQ ID NO:14), and a single stranded conformation polymorphism between 57BL/6J and CAST/Ei mice was detected in MDE gels as previously described (27). The polymorphism was mapped on a panel of DNA from 57 C57BL/6J x CAST/Ei)F1 x C57BL/6J backcrossed mice, donated by
- 20 The Jackson Laboratory Mouse Mutant Resource, which contains a large number of previously typed markers on all chromosomes (28).

*c-Jun N-terminal kinase assays.* 2-5x10<sup>6</sup> cells were incubated for 1-2 hours at 37°C, 5% CO<sub>2</sub> on plates coated with the  $\alpha$ -FLAG M2 antibody (10  $\mu$ g/mL). The cells were

- 25 treated with either soluble TRANCE in 10% glycerol/PBS solution or an equal volume of 10% glycerol/PBS solution before harvesting at the indicated time points, and frozen in a dry ice/ethanol bath. Cells were lysed with Triton Lysis Buffer [20 mM Tris•Cl (pH 7.5), 137 mM NaCl, 1 mM PMSF, 5 mM EDTA, 2 mM EGTA, 1 mM Na<sub>3</sub>VO<sub>4</sub>, 25 mM  $\beta$ -glycerophosphate, 50 mM NaF, 10 mM sodium
- 30 pyrophosphate, 15% glycerol, 1% Triton X-100], spun down in a microcentrifuge to remove cell debris, and supernatants were incubated with goat  $\alpha$ -JNK1 Ab (0.3  $\mu$ g;

Santa Cruz Biotechnology) for 2 h at 4°C. Protein A sepharose was added for 1 h and the beads were washed 2 times with Triton Lysis Buffer then 2 times with JNK Reaction Buffer [25 mM HEPES (pH 7.4), 25 mM  $\beta$ -glycerophosphate, 25 mM  $\text{MgCl}_2$ , 2 mM DTT, 0.1 mM  $\text{Na}_3\text{VO}_4$ ]. For the kinase reaction, 30  $\mu\text{L}$  of JNK  
 5 Reaction Buffer containing 1.5-3.0  $\mu\text{g}$  of purified GST-c-Jun(1-79) (generously donated by Dr. H. Hanafusa, The Rockefeller University), 0.5  $\mu\text{Ci}$  of  $\gamma\text{-}^{32}\text{P}$  ATP and ATP (20  $\mu\text{M}$ ) was incubated with the immunoprecipitated JNK for 20 min at 30 °C. The reactions were stopped with 2X loading buffer, boiled for 5 min and run on a 12% SDS-PAGE gel as previously described. (29)

10

### Results and Discussion

*Identification of mouse and human TRANCE.* The molecular defects in KIT50.1.9.1, a mutant T cell hybridoma resistant to TCR-mediated apoptosis (23) were investigated by comparing its gene expression with that of KMLs8.3.5.1, the parental cell line  
 15 sensitive to TCR-mediated apoptosis. Differentially expressed genes between TCR-stimulated KIT50.1.9.1 (KIT50.1.9.1+) and TCR-stimulated KMLs8.3.5.1 (KMLs8.3.5.1+) were isolated using suppression subtractive hybridization, a cDNA subtraction technique based on suppression PCR that is sensitive to rare transcripts (30). After subtracting KIT50.1.9.1+ cDNA from KMLs8.3.5.1+ cDNA a mini-library  
 20 was generated by randomly subcloning the subtracted PCR products. The plasmid library was then subjected to differential screening using KIT50.1.9.1+ cDNA and KMLs8.3.5.1+ cDNA as probes. Of the 347 plasmids screened, 76 produced a stronger signal with the KMLs8.3.5.1+ probe than with the KIT50.1.9.1+ probe. One positive, designated 8-50.51, is shown in FIGURE 5A. In contrast, Nur77, a gene  
 25 whose expression is induced normally in both cells (data not shown) produced similar signals with both probes indicating that an equivalent amount of labeled probe was used from each cell line. Sequencing of 8-50.51 revealed an 87 bp DNA fragment with no homology to any genes in the Genbank database. To confirm differential expression of 8-50.51 we probed a Northern blot containing unstimulated and TCR-  
 30 stimulated KMLs8.3.5.1 and KIT50.1.9.1 poly A(+) RNA. The probe identified a 2.2-2.3 kB message that was highly induced in TCR-stimulated in KMLs8.3.5.1 but only

weakly induced in TCR-stimulated KIT50.1.9.1 (FIGURE 5B).

Using 8-50.51 as a probe we screened a KMLs8.3.5.1+ cDNA library to obtain a full length clone. The full length cDNA (FIGURE 6A) is 2237 bp in length with a canonical Kozak consensus sequence starting at 137 bp from the 5' end of the clone.

5 This translation initiation site permits the synthesis of a 316 amino acid protein with a hydrophobic transmembrane domain and no identifiable signal sequence strongly suggesting a type II integral membrane protein topology. A comparison of extracellular domains revealed similarity of the protein with mouse TRAIL (20%), FasL (19%) and TNF (17%). Alignment with selected members of the TNF family

10 demonstrates high identity, especially in regions forming the  $\beta$  strands as estimated from the TNF crystal structure (31) (FIGURE 6B). Due to the clear similarity of this gene with the TNF family members this protein was termed TRANCE. A FLAG-tagged full length protein with an estimated molecular weight of 35 kD was detected by Western blotting as a ~ 45 kD band suggesting that TRANCE is post-

15 translationally modified (data not shown). Putative *N*-linked glycosylation sites are indicated (FIGURE 6A). The FLAG-tagged TRANCE could not be immunoprecipitated with Fas, DR3/wsl-1/TRAMP/Apo-3, CD30, TNFR2, or HVEM/ATAR immunoadhesins suggesting that TRANCE does not bind to these receptors (data not shown). A partial human TRANCE cDNA, cloned from a human

20 thymus cDNA library, is 83% identical to the mouse TRANCE ectodomain suggesting that the function of this gene is highly conserved between mouse and human.

*Regulation and tissue distribution of TRANCE.* The signaling capabilities and

25 biological functions of the TNF family appear redundant. Yet specificity clearly exists, as shown by gene-knockout studies, in which the deletion of one family member cannot be fully compensated by the others. Specificity may be achieved by restricting the expression of these genes to particular cells and tissues and or by linking their induction to different regulatory pathways. Temporal regulation of the

30 TNF family members may also be important in properly coordinating their biological effects *in vivo* (1). The regulation of TRANCE induction by the TCR was studied in

T cell hybridomas with cycloheximide (CHX), an inhibitor of translation, and FK506, a FKBP ligand that inhibits calcineurin (PP-2B) (FIGURE 7A, Left). Without inhibitors, TRANCE expression began 1 h after TCR-stimulation and reached a maximal level at 2.5 h. FasL was also highly induced by TCR-stimulation, however, its expression began at a later time point. CHX failed to inhibit the induction of TRANCE by the TCR indicating that TRANCE is an immediate early gene. In contrast, CHX completely abrogated the induction of FasL by the TCR. Thus, TRANCE, like TNF (32), is an immediate early gene with a relatively rapid onset of expression after TCR stimulation whereas FasL induction is delayed and requires de novo protein expression for its synthesis. Cyclosporin A, and FK506, both inhibitors of calcineurin, repress TCR-mediated TNF induction (32) and NFATp deficient mice fail to upregulate FasL, CD40L and TNF expression in response to TCR stimulation (33). Therefore, FasL, CD40L and TNF appear to be regulated by calcineurin-dependent signaling pathways involving the NFAT family of transcription factors. In the presence of FK506, the induction of TRANCE and FasL is blocked (FIGURE 7A, Left) suggesting that TRANCE, like several other TNF-related ligands, is controlled by NFAT proteins.

To examine TRANCE regulation in non-transformed cells, Northern analysis was performed on concanavalin A (ConA) and IL-2 stimulated LNTC, a model of antigen-mediated T cell proliferation and on proliferating LNTC re-stimulated with  $\alpha$ -CD3 $\epsilon$  Ab, a model of peripheral T cell clonal deletion (17). ConA and IL-2 stimulated T cells express relatively low amounts of TRANCE message whereas FasL expression is high (FIGURE 7A, Right). However, after re-stimulation with an  $\alpha$ -CD3 $\epsilon$  Ab TRANCE was significantly upregulated suggesting that TRANCE may play a role in antigen-induced T cell death.

Northern blot analysis revealed that TRANCE expression is restricted to the thymus and lymph node (FIGURE 7B, Left). This pattern of expression differs from the pattern exhibited by TRAIL/Apo-2L and FasL, which are expressed in both lymphoid and non-lymphoid organs, but is similar to the pattern exhibited by lymphotoxin- $\beta$ ,

which is restricted to spleen. In addition, TRANCE is abundant in lymph node-derived T cells (LNTC) but not in splenic B cells (FIGURE 7B, Right). Thus, TRANCE is expressed specifically in T cells and in T cell rich organs, although its expression in other cell-types cannot be ruled out.

5

*Chromosomal Mapping of TRANCE.* The murine *TRANCE* locus was mapped to mouse chromosome 14 by use of an intersubspecific backcross (27, 28). In 57 backcross mice *TRANCE* showed two recombinants with the *Rb1* locus (Lod 13.4) and nine recombinants with *Rps10-rs4* (Lod  $>>6.4$ ) (data not shown). After inferring marker genotypes from recombinant mice, incorporating other markers and minimizing double crossovers, the gene order and map distances (cM $\pm$ SE) were: *Rb1* - (1.5 $\pm$ 1.0) - *TRANCE* - (1.5 $\pm$ 1.1) - *Rps10-rs4* - (3.7 $\pm$ 1.6) - *Rpl36-rs2* - (6.4 $\pm$ 2.1) - *Rpl7-rs2* - (4.2 $\pm$ 1.7) - *Dct*. *TRANCE* is located on mouse chromosome 14 near a non-MHC locus suggestively linked to autoimmune nephritis in NZB mice (34).

15 implicating *TRANCE* in the regulation of immune-tolerance. Human *TRANCE* was localized by radiation hybrid mapping at 3.98 cR (approximately 800 kB) from the marker, CHLC.GATA6B07 (D13S325), located at 117 cR on the WI radiation hybrid framework of chromosome 13 (data not shown). Superposition of this map with the cytogenetic map of human chromosome 13 allowed the assignment of *TRANCE* to

20 chromosomal band 13q14.

*Biochemical function of TRANCE.* A soluble form of TRANCE containing the entire ectodomain fused to an N-terminal FLAG epitope (TRANCE-Ecto) was constructed to examine the biochemical function of TRANCE and to identify the cellular targets

25 that respond to this protein. TRANCE-Ecto, when expressed in 293T cells and purified to homogeneity, has an apparent molecular weight of  $\sim 37$  kD by SDS-PAGE analysis (FIGURE 8A). Since its calculated molecular weight is 27.5 kD, this data suggests that the TRANCE-Ecto protein is post-translationally modified similarly to the FLAG-tagged membrane bound protein. JNK is a signal transducing molecule

30 commonly activated by TNF-related ligands. Therefore, JNK activation was assessed by the soluble TRANCE protein in thymocytes, LNTC, purified splenic B cells and

bone-marrow-derived dendritic cells (BMDC). JNK is rapidly activated in thymocytes (3-fold induction at 10 min), LNTC (2-fold induction at 5 min) (Fig. 4B) and T cell hybridomas (2-fold at 10 min; data not shown). In contrast, no effect was observed in B cells, or in BMDC (Fig. 4B). B cells and BMDC may not be sensitive to soluble TRANCE at the concentration used in this assay due to the lack of an adequate number of cell surface receptors. Another possibility is that only certain cell types express JNK-activating signal transducing molecules. These results suggest that the TRANCE recombinant protein is biologically active and appears to stimulate JNK specifically in cells of the T cell lineage.

10

Described herein is the cloning of a novel member of the TNF cytokine gene family whose expression is restricted to T cells and lymphoid organs and can participate in signaling to T cells, implicating TRANCE in the regulation of T cell dependent immune responses. TRANCE was obtained through a genetic screen and it appears associated with cell death and not cell survival or proliferation (FIGURE 5B and FIGURE 7A, Right). Due to the multi-functional role other TNF-related molecules exhibit it is likely that TRANCE plays a role in cell activation, proliferation, survival or death depending on the context in which it is expressed and the nature of the target cell. In support of this, TRANCE activates JNK, a kinase with pleiotropic biological effects.

20

25

30   EXAMPLE 2:                   TRANCE, a New TNF Family Member Predominantly  
   Expressed in T cells, is a Dendritic Cell Specific  
   Survival Factor.

TRANCE is a new member of the TNF family that is induced upon T cell receptor

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engagement and activates c-Jun N-terminal kinase (JNK) following interaction with its putative receptor (TRANCE-R) (Wong, et al., *J. Biol. Chem.*, 272;25190-25194). TRANCE expression is restricted to lymphoid organs and to T cells. Disclosed herein is a showing that high levels of TRANCE-R are detected on mature dendritic cells (DC) but not on freshly isolated B cells, T cells or macrophages. Signaling by TRANCE-R appears dependent on TNF receptor-associated factor 2 (TRAF2), since JNK induction is impaired in cells from transgenic mice over expressing a dominant negative TRAF2 protein. TRANCE inhibits apoptosis of mouse bone-marrow derived DC and human monocyte-derived DC in vitro. The resulting increase in DC survival is accompanied by a proportional increase in DC-mediated T cell proliferation in an MLR. TRANCE upregulates Bcl-x<sub>L</sub> expression suggesting a potential mechanism for enhanced DC survival. TRANCE does not induce the proliferation of B cells or increase the survival of T or B cells. Therefore, TRANCE is a new DC restricted survival factor that mediates T cell-DC communication and provides a tool to modulate DC activity, and hence immune response.

Apoptosis plays a critical role in the development and maintenance of the immune system (35-37). Members of the tumor necrosis factor (TNF) family can regulate apoptosis in addition to an array of other biological effects such as cell proliferation and differentiation (38). Despite the functional redundancy of this family, specificity may be accomplished by coordinating the spatial and temporal expression of TNF-related ligands and their receptors and by restricting the expression of signal transduction molecules to specific cell types. TNF receptors interact with a family of molecules called TRAFs (TNF receptor-associated factors)<sup>1</sup> that act as adaptors for downstream signaling events (39). For example, TRAF2 activates NF- $\kappa$ B (40) and also c-Jun N-terminal kinase (JNK) (41-43). The biochemical events leading to apoptosis involve the caspase family of cysteine proteases (44), whereas NF- $\kappa$ B appears to inhibit cell death (45). The TNF receptor family can also regulate apoptosis by modulating the expression of Bcl-2 and Bcl-2-related proteins (46, 47). Recent data indicates that the Bcl family controls apoptosis by altering transmembrane conductance in mitochondria and by preventing the activation of

caspases (48-50).

An important role of TNF members in dendritic cells (DC) biology has recently emerged. DCs have several specializations that lead to the stimulation of naive T cells and play a role in the initiation of the immune response (51). TNF- $\alpha$  and CD40L are molecules involved in the differentiation of DC from CD34<sup>+</sup> bone-marrow or cord blood progenitors (52-54). Moreover, CD40L increases DC survival, upregulates MHC and costimulatory molecule expression and induces the expression of a variety of cytokines (e.g., IL-12) in DC (55). Both CD40 and TNFR interact with TRAF2, suggesting that TRAF2 plays a role in DC function.

Recently, TRANCE (TNF-related activation-induced cytokine), a novel ligand of the TNF family was cloned during a search for apoptosis regulatory genes. Remarkably, TRANCE expression is restricted to lymphoid specific organs and is selectively expressed in T cells (56). Disclosed herein is the discovery that TRANCE-R signals via TRAF2 in thymocytes and increases DC survival by upregulating Bcl-x<sub>L</sub> expression, a property shared with CD40L. However, unlike CD40L, TRANCE selectively acts on mature DC but not on B cells. In addition, high levels of the TRANCE-R are only detected on DC suggesting that a major function of TRANCE *in vivo* is to modulate DC activity. Hence, TRANCE can also modulate T cell activation and immune response to an antigen.

### Materials and Methods

*Expression and Purification of Soluble TRANCE.* A FLAG epitope-tagged TRANCE molecule (FLAG-TRANCE) was expressed in 293T cells and purified as described (56). To create a human CD8-TRANCE recombinant molecule (hCD8-TRANCE), the extracellular domain of murine TRANCE (a.a. 245-316 of Figure 4 (SEQ ID NO:4)) was fused to human CD8 $\alpha$  (a.a. 1-182) and produced in a baculovirus expression system according to the manufacturer's instructions (BaculoGold, Pharmingen, Dan Diego, CA). hCD8-TRANCE was purified on CNBR-activated Sepharaose gel conjugated to OKT8 following the manufacturer's protocol (Pharmacia



Biotech, Piscataway, NJ). mCD8-CD40L in insect cell culture supernatant was kindly provided by Dr. Randolph J. Noelle (Dartmouth Medical School, Hanover, NH).

*Mice.* C57BL/6 (H-2<sup>b</sup>) and BALB/c (H-2<sup>d</sup>) mice were from Taconic Farms (Germantown, NY). Transgenic mice expressing a dominant negative form of TRAF2 (TRAF2.DN) were engineered as described (57).

*Cells.* Bone-marrow derived DC (BMDC) were generated as described (58) and were used on day 8 of culture. Enriched populations of fresh lymph node or splenic DC were prepared by digesting organs with collagenase then selecting for low density cells via centrifugation on a Nycodenz column (14.5% w/v in PBS + 5 mM EDTA; Nycomed, Oslo, Norway) for 15 min. at 4°C. Mature spleen DC were prepared by culturing freshly isolated spleen DC overnight as described (59). The cytokine-induced generation of human DC from PBMCs was performed as described (60). After 2 days in monocyte conditioned medium (MCM), TRANCE or PBS was added to the DCs. Lymph node T cells (99% CD3<sup>+</sup> as assessed by flow cytometry) were prepared by magnetic bead depletion (DynaL, Oslo, Norway) of class II, B220, NK1.1, and F4/80 positive cells. B cells were prepared by magnetic depletion of Thy1.2 positive cells (DynaL). Cell viability was assayed by trypan blue exclusion or by propidium iodide uptake.

*Flow cytometry.* DC phenotype was assessed by flow cytometry as described (61) using the following FITC or PE-conjugated mAbs: H-2K<sup>b</sup>, I-A<sup>b</sup>, ICAM-1, CD11b, CD11c, CD80, CD86, CD25, CD40 (PharMingen). Other mAbs used were biotinylated  $\alpha$ -Fas, CD3-FITC, B220-FITC (PharMingen) and NLDC-145-FITC. The expression of TRANCE-R was assessed using the hCD8-TRANCE fusion molecule at 10  $\mu$ g/mL at 4°C followed by biotinylated OKT8 mAb and then streptavidin-PE (BioSource International, Camarillo, CA). Negative controls were performed by omitting hCD8-TRANCE. For analysis of TRANCE-R expression on resting B cells and fresh DC, low density cells were stained with FITC-B220 or FITC-CD11c, respectively and analyzed on a "FACSCAN" (Becton Dickinson, Mountain View,

CA).

*Mixed leukocyte reaction.* BMDC treated for 48 hours in the presence or absence of recombinant TRANCE were cultured with  $1 \times 10^5$  purified allogeneic T-cells in flat bottom 96 well plates in a final volume of 200  $\mu$ l for 3 days and then pulsed for eight hours with 0.5  $\mu$ Ci of  $^3$ [H]-Thymidine (Dupont NEN®, Boston, MA). The cells were then harvested on glass fiber filters and  $^3$ [H]-Thymidine incorporation was measured using a standard scintillation-detection procedure.

- 10 *c-Jun N-Terminal Kinase Assays.*  $2-5 \times 10^6$  cells from TRAF2.DN transgenic mice or from control littermates were incubated 1-2 hours at 37°C on plates coated with OKT8 antibody (10  $\mu$ g/mL). The cells were treated with either soluble TRANCE or an equal volume of PBS before harvesting at the indicated time points and frozen in a dry ice/ethanol bath. JNK was immunoprecipitated with  $\alpha$ -JNK1 antibody (Santa Cruz Biotechnology, Santa Cruz, CA) and kinase activity assessed as described (56).

- 20 *Western and RT-PCR analysis of Bcl-x<sub>L</sub> and Bcl-2.* BMDC ( $8 \times 10^6$ /well) were cultured in RPMI in six well plates and treated with PBS, FLAG-TRANCE (1  $\mu$ g/mL) or soluble CD40L for 0 or 24 hours. The cells were lysed, and 50  $\mu$ g of protein from each sample were resolved on a 12% SDS-PAGE gel and transferred to Immobilon-P membranes (Millipore, Bedford, MA). The blots were blocked in 5% skim milk, probed with  $\alpha$ -Bcl-2 (4C11) or  $\alpha$ -Bcl-x<sub>L</sub> (236) [Kindly provided by Dr. Gabriel Nunez, Univ. of Michigan] and detected with the appropriate HRP-conjugated secondary antibodies and enhanced chemiluminescence substrate (ECL, Amersham Corp., Arlington Heights, IL). For RT-PCR analysis of *bcl-x<sub>L</sub>* mRNA expression, BMDC ( $2 \times 10^6$  cells/well) were cultured in 24 well plates, treated with the appropriate reagents and quickly frozen in a cry ice/ethanol bath at the various time points. Total RNA was extracted (RNEasy, Qiagen Inc., Chatsworth, CA) and cDNA was diluted to allow PCR amplification to occur as a linear function of starting concentrations. PCR was performed using the conditions and primers as described (47).

### Results and Discussion

*TRANCE-R is expressed at high levels in dendritic cells.* To identify cells that express TRANCE-R, hCD8-TRANCE was used as a molecular probe for FACS analysis.

TRANCE-R was detected on mature BMDC, freshly isolated lymph node DC and  
 5 freshly isolated spleen DC (FIGURE 5). TRANCE-R was greatly upregulated upon the maturation of spleen DC induced by overnight culture. No expression could be detected on freshly isolated lymph node B cells, lymph node T cells, thymocytes or peritoneal macrophages. Therefore, the highest levels of TRANCE-R expression are found on mature DC and suggest that the major role of TRANCE is restricted to DCs.

10

*TRANCE is a dendritic cell survival factor.* The biological effects of TRANCE were further studied on mature DCs. TRANCE-treated DCs formed densely packed clusters while control, untreated cells exhibited relatively sparse aggregates (FIGURE 10A). In addition, mature BMDC treated with FLAG-TRANCE were significantly  
 15 protected from spontaneous cell death compared to untreated cells. This effect was dependent on the dose of TRANCE (FIGURE 10B). hCD8-TRANCE elicited similar results (data not shown). This effect was not due to increased cell proliferation since the total number of cells remained the same over time (data not shown). TRANCE significantly prevented DC cell death until day 6, whereas untreated cells were almost  
 20 completely dead by day 3 (FIGURE 10C). A similar effect on DC survival was observed with human monocyte-derived DC (FIGURE 10D). Confirming previous data CD40 ligand (CD40L) also induced the clustering of DC (data not shown) (62, 63) and enhanced DC survival comparably to TRANCE (FIGURE 10C).

25 CD40L upregulates the anti-apoptotic molecule, Bcl-x<sub>L</sub>, in B cells and protects them from Ig-receptor mediated cell death (47). In addition, CD40L upregulates Bcl-2 in human DC derived from CD34<sup>+</sup> progenitor cells, a phenomenon which was correlated with a resistance to Fas mediated apoptosis (46). To determine whether TRANCE can influence Bcl-2 or Bcl-x<sub>L</sub> their expression in DC stimulated with TRANCE or CD40L  
 30 was measured by Western analysis. BMDC expressed relatively high levels of Bcl-2 and relatively low levels of Bcl-x<sub>L</sub> after reaching maturity in GM-CSF (FIGURE 10E,

0 hr). FLAG-TRANCE and CD40L stimulation lead to increased Bcl-x<sub>L</sub> expression by 24 hours. Bcl-x<sub>L</sub> expression was nearly absent in cells treated with medium alone. *bcl-x<sub>L</sub>* mRNA was upregulated in TRANCE-treated DCs suggesting a transcriptional as opposed to post-transcriptional regulation (data not shown). In contrast Bcl-2  
 5 levels were decreased in both the TRANCE-treated and untreated cells (FIGURE 10E). These results suggest that TRANCE, in addition to CD40L, upregulates Bcl-x<sub>L</sub> in DC which enhances their viability *in vitro*.

*TRANCE enhances DC-mediated T cell proliferation.* To examine the functional  
 10 consequences of TRANCE on DCs the MLR stimulating ability of DC treated with TRANCE was measured. Increasing doses of FLAG-TRANCE enhanced DC survival at 48 hours which, in turn, led to a proportional increase in the stimulation of T cell proliferation (FIGURE 11A). When equivalent numbers of viable TRANCE-  
 15 treated or untreated DC were used in an MLR, there were no differences in T cell proliferation, suggesting that changes in the expression of costimulatory and antigen presenting molecules did not account for the enhanced T cell proliferation (FIGURE 11B). To verify this, the levels of several surface markers were tested by FACS to  
 20 evaluate any TRANCE-mediated changes to the DC phenotype. There was a slight but reproducible downregulation of MHC II expression and a slight upregulation of MHC I expression (FIGURE 11C). There were no TRANCE-mediated perturbations in the expression of the costimulatory molecules CD80 (B7-1) or CD86 (B7-2), and  
 no changes in the expression of the adhesion molecules ICAM1, CD11b and CD11c. Interestingly, CD40 expression increased but Fas or TRANCE-R did not. In sum, TRANCE enhances DC mediated T cell proliferation by increasing the survival of  
 25 DCs.

*TRANCE does not affect B cell proliferation.* Expression of high levels of the TRANCE-R appeared restricted to DC by FACS analysis. However, it was found that TRANCE could activate JNK in thymocytes (56) suggesting that FACS analysis  
 30 might lack the sensitivity to detect low levels of receptor. To further examine the specificity of TRANCE for DCs, its ability to induce B cell proliferation or survival

was tested, two functions mediated by CD40L. Recombinant hCD8-TRANCE, tested for its anti-apoptotic function in BMDC, could not stimulate B cell proliferation (FIGURE 12) nor could it activate JNK activation (56). In contrast, CD40L efficiently stimulated B cell proliferation in a dose dependent manner (FIGURE 13).

5 Finally, TRANCE could not prevent the spontaneous apoptosis of B cells and T cells as assessed by propidium iodide uptake (data not shown). Therefore, functionally, TRANCE appears to exhibit different cellular specificities and functions when compared to CD40L.

10 *TRANCE-mediated JNK induction requires functional TRAF2.* Recruitment of TRAF2 to the TNFR complex or the CD40 receptor complex is necessary for JNK activation (41-43, 57). To test the possibility that TRANCE-R also signals via TRAF2, we analyzed TRANCE-mediated JNK activation in thymocytes from transgenic mice over expressing a dominant negative form of TRAF2 (TRAF2.DN)  
 15 (57). JNK activity peaked 2.5 fold over unstimulated cells at 5 minutes in control littermates whereas JNK induction was significantly reduced in TRAF2.DN thymocytes (FIGURE. 9). These results suggest that signaling from the TRANCE-R requires TRAF2. TRANCE-mediated JNK induction in DC could not be assayed since TRAF2.DN expression has been restricted to lymphocytes in the TRAF2.DN  
 20 transgenic mice. In addition, JNK activity was constitutively high in mature DC (56), which are also known to have high levels of activated NF- $\kappa$ B (64), thus confounding detection of increased JNK activity.

It has been demonstrated that TRANCE, in addition to CD40L, is a modulator of DC  
 25 function. Similar to CD40L, TRANCE modulates the survival of mature DC by regulating the expression of Bcl-x<sub>L</sub>. In contrast to CD40L, however, TRANCE does not act on other APC such as B cells. The signal transduction pathways downstream of TRANCE-R that regulate DC activities remain unknown. TRANCE appears to signal via TRAF2, at least in thymocytes, suggesting that TRAF2 may play a critical  
 30 role in mediating signals for differentiation, activation and survival in DC.

These findings complement the description of the selective expression of this new TNF family member in T cells. The high level of expression of TRANCE-R on DC suggests a specific role for TRANCE in T cell-DC communication during the primary immune response. Rapid upregulation of TRANCE upon TCR engagement on T cells (56) could specifically enhance the survival of DC during antigen presentation. Both antigen-specific T cells and the antigen presenting DC would therefore depend on each other for activation and survival, respectively. Mature DC which fail to present antigen to T cells would not receive T cell help and thereby die of neglect. This T cell-DC interaction is likely to occur in the T cell area of lymphoid organs which contain DC of mature phenotypes (65). DC can only be detected in afferent lymph not efferent lymph suggesting that DCs are destined to die when they migrate to the lymph node. TRANCE may be important to maintain DC survival perhaps acting prior to CD40L since TRANCE is an immediate early gene (56). Many experiments indicate that DC pulsed *ex vivo* with an antigen can be used to induce immunity to tumor or viral antigens *in vivo* (66). TRANCE can provide a tool to specifically enhance DC function by enhancing their survival *in vivo*.

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Many other variations and modifications of the invention will be apparent to those skilled in the art without departing from the spirit and scope of the invention. The above embodiments are, therefore, merely exemplary, and all such variations and modifications are intended to be within the scope of the invention as defined in the appended claims.

It is further understood that all base sizes or amino acid sizes, and all molecular weight or molecular weight mass values given for nucleic acids or polypeptides are approximate, and are provided for description.

Various publications are cited herein, the disclosures of which are incorporated by

reference in their entirety.

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